WOKING PARK - FUEL CELL COMBINED HEAT AND POWER SYSTEM

Final Report

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ABSTRACT

This report covers the aims and objectives of the project which was to design, install and operate a fuel cell combined heat and power (CHP) system in Woking Park, the first fuel cell CHP system in the United Kingdom. The report also covers the benefits that were expected to accrue from the work in an understanding of the full technology procurement process (including planning, design, installation, operation and maintenance), the economic and environmental performance in comparison with both conventional UK fuel supply and conventional CHP and the commercial viability of fuel cell CHP energy supply in the new deregulated energy markets.

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1. INTRODUCTION

1.1 Background to the Project

Woking Borough Council has implemented a series of sustainable energy projects in the past 12 years, including the UK's first small-scale combined heat and power (CHP)/heat fired absorption chiller system, first local authority private wire residential CHP systems, largest domestic photovoltaic/CHP installations, first local sustainable community energy systems, first fuel cell CHP system and first public/private joint venture Energy Services Company or ESCO.

In recognition of this pioneering work the Council gained the **Queen's Award for Enterprise: Sustainable Development 2001** in respect of its Energy Services activities in the development of Local Sustainable Community Energy Systems, the only local authority ever to receive a Queen's Award for Enterprise.

Since the Council implemented it's energy efficiency and environmental policies in 1990/91 (the base year), it achieved it's target to reduce energy consumption by 40% in 10 years from 1991/92 and 2000/2001, as follows:-

Energy Consumption Savings	170,170,665 kWh	43.8% Saving
Carbon Dioxide CO_2 Emissions Savings	96,588 Tonnes	71.5% Saving
Nitrogen Oxides NO_x Emissions Savings	319.1 Tonnes	68.0% Saving
Sulphur Dioxide SO_2 Savings	976.6 Tonnes	73.4% Saving
Water Consumption Savings	340,011,000 Litres	43.8% Saving
Savings in Energy and Water Budgets	£4,889,501	34.3% Saving

The above savings are for corporate property and housing stock, where the Council pays the energy and water bills, and exclude Council tenant and private sector savings brought about by the Council's Housing energy conservation and CHP/renewable energy programmes.

The Council's innovative energy efficiency recycling fund, where financial savings achieved by energy and water efficiency projects are ploughed back into the capital fund creating an ongoing recycled capital fund (ESCO finance model) has led to a total investment of **£2.7M** over the previous 11 years from the original capital fund of **£0.25M** established in 1990/91 which has enabled savings of nearly **£4.9M** over the same period to be made resulting in current annual savings of over **£885,000 a year**.

1.2 Climate Change Strategy

In December 2002, the Council's energy efficiency policy was replaced by the Climate Change Strategy for Woking, not just for Council buildings and transport but for the Borough as a whole, shifting the focus from savings in kWh's of energy to savings in tonnes of CO_2 as well as adapting to a changing climate. The key three principles of the Strategy are:-

- Adopting an overall target to reduce Woking's CO_2 equivalent emissions to 80% of its 1990 level by 2090 in steps of 10% up to 2050 and 5% from 2050 to 2090;

- Adopting the concept of an Environmental Footprint for the Borough which has as its base 1,060,000 tonnes of CO_2 equivalent emissions of greenhouse gases; and
- Declaring itself Climate Neutral and setting up a Climate Change Fund.

As part of a number of action plans the Strategy adopts targets for purchasing 20% of the Council's electrical energy requirements from renewable sources and 100% of the Council's electrical and thermal energy requirements from sustainable energy (including CHP) sources by 2010/11.

By 2001/02 the Council had already reduced CO_2 equivalent emissions by 8.01% of the whole of the Borough's CO_2 emissions in 1990 through its own actions alone.

1.3 Woking Park Fuel Cell CHP Project

The fuel cell combined heat and power (CHP) system is located in Woking Park and serves the Leisure Lagoon, Pool In The Park (competition and training pools) and Woking Leisure Centre (dry sports centre) and is the first fuel cell CHP in the UK.

In commemoration of the fuel cell as a British invention a statue to Sir William Grove ('Father of the Fuel Cell') was erected in the Grove Garden adjacent to the fuel cell CHP. The Grove artist was Ulli Knall.

The fuel cell CHP is visible to the public and is provided with a technology information mural/display and viewing area for education purposes which includes the history of the fuel cell, how the system works in Woking Park and how renewable energy can be integrated with the Hydrogen Economy to provide continuous renewable energy for the world's electrical, thermal and transport energy needs. The official biography for Sir William Grove, sponsored by the World Fuel Cell Council and the Royal Institution of Great Britain, is also included in the display.

1.4 US Department of Energy Climate Change Fuel Cell Program

As the Council had earmarked finance for a conventional CHP system at Woking Park out of its energy efficiency programme in any case, this became the trigger to secure sponsorship for the difference in cost between a conventional CHP and a fuel cell CHP and perhaps more importantly a suitable host site for the technology. Part sponsorship was secured from the UK Department of Trade and Industry and Advantica Technologies Ltd., and the Woking Park Fuel Cell CHP Steering Committee was established to move the project forward.

In order to complete the sponsorship needed to implement the project the Council submitted a solicitation for financial assistance application to the US Department of Energy (DE-PS26-99FT40516) under the Climate Change Fuel Cell Program on 25 March 1999. A Federal grant was awarded on 9 July 1999 and taken up by the Council on 16 July 1999.

The aims and objectives of the US DoE project was to design, install and operate a fuel cell CHP system in Woking Park. Specific objectives was to establish the economic and environmental performance of the fuel cell CHP in comparison with both the conventional UK fuel supply and conventional CHP and its future commercial viability in a green energy ESCO market.

The fuel cell CHP acceptance tests were carried out on 11 August 2000 and the fuel cell CHP was commissioned on 21 December 2001.

2. EXECUTIVE SUMMARY

This report covers the aims and objectives of the project which was to design, install and operate a fuel cell combined heat and power (CHP) system in Woking Park, the first fuel cell CHP system in the United Kingdom. The report also covers the benefits that were expected to accrue from the work in an understanding of the full technology procurement process (including planning, design, installation, operation and maintenance), the economic and environmental performance in comparison with both conventional UK fuel supply and conventional CHP and the commercial viability of fuel cell CHP energy supply in the new deregulated energy markets.

The first part of the report covers the design, installation and operation of the fuel cell CHP system UTC Fuel Cells Model No. PC25/C (formerly IFC PC25C) Unit. The report continues with a description of the application at the Woking Park site and the planning, preparation, specification, tendering, economics, funding and approvals issues, which had to be addressed for the project to succeed. The particular planning procedures and arguments that were put to Council Officers and Members ultimately to gain their full support are also covered as are the differences in the installation requirements of the fuel cell CHP compared to conventional CHP. A description of the commissioning and testing process up to the point of acceptance of the unit is also given.

An explanation of the Council's public/private joint venture Energy Services Company: Thameswey approach to delivering such projects and the private wire concept to enable the true economic benefits of distributed generation to be extracted from such projects is also given in this part of the report.

The second part of the report deals with the economic and environmental performance of the fuel cell CHP in comparison with both the conventional UK fuel supply and conventional CHP and its future commercial viability in a green energy ESCO market.

The economic performance of the fuel cell CHP is tested against a simple payback criteria and compared with the conventional CHP in the Leisure Lagoon. The UK deregulated energy market is used as the benchmark for the conventional UK fuel supply market. Since the fuel cell CHP technology is known not to be commercially viable as a direct replacement for conventional CHP at the present time a comparison has also been made against the commercial viability of another expensive green technology, ie., large scale photovoltaics since Woking has the largest concentration of solar energy photovoltaics in the UK. This will provide a more meaningful economic comparison since fuel cells are more likely to compete with or compliment renewable energy technologies on environmental grounds for what could be a significant niche green market for fuel cells prior to full commercialisation.

The environmental performance of the fuel cell CHP is tested against the UK Combined Heat and Power Quality Assurance (CHPQA) programme a mechanism for obtaining exemption from the UK Climate Change Levy payable on fossil fuels and centralised power generation. An explanation is given of the CHPQA and actual CHPQA Quality Index's (QI) are used not just for the fuel cell CHP but also in comparison with a number of the Council's conventional CHP systems. This comparison is for a real practical tax credit based on environmental performance. For good measure an environmental comparison is also made with solar energy photovoltaics.

3. EXPERIMENTAL, RESULTS AND DISCUSSION (PART 1)

3.1 Introduction

Due to the nature of the project the experimental, results and discussions are incorporated together in this section and also in 4. Experimental, Results and Discussion (Part 2).

At the time of the initiation of the project the PC25 was the only fuel cell cogeneration unit available commercially. The PC25 is a phosphoric acid fuel cell CHP, manufactured in the United States by UTC Fuel Cells (formerly International Fuel Cells (IFC)) previously marketed through ONSI (a sister company of IFC). The PC25 delivers 200kW of electrical power and commensurate heat at various temperatures, with an overall full load electrical generation efficiency of approximately 40% (lower calorific value, LCV). The thermal energy output has been recently increased with the Model C from 700,000 BTU/h (205 kW) to 900,000 BTU/h (264 kW) and in some instances up to 1,000,000 BTU/h (293 kW) where most of the low-grade heat is extracted and utilised. The Woking Park fuel cell CHP has an expected electrical efficiency of 40% and an overall heat output of up to 900,000 BTU/h, 264kW (increasing to 280kW with the recovery of the high grade circuit return temperature through the low grade circuit).

For such a project to be successful, the right combination of the potential host site and organisation along with a funding partnership prepared to back a project that, by its very nature, does not meet normal investment criteria, is needed. Any new technology of this type tends to be offered to the market at a price some way above that demanded by conventional (in this case mostly reciprocating engine based) products. To be of interest it must offer some additional ‘next generation’ benefits, which include lower emissions, in part through higher electricity and overall generation efficiency, lower noise, greater reliability and security of supply. The PC25 is a highly developed product, offering extensive operational experience worldwide. In the United States, the PC25 is often used as the primary power supply to a facility, with the local utility network as a backup, able to operate in grid independent or island generation mode.

3.2 Project Funding

The high cost of the fuel cell CHP required grant aid from the UK Department of Trade and Industry (DTI) and Advantica Technologies Ltd., (previously British Gas and then later demerged into BG, Centrica and Lattice Groups) to reduce the risk of the project to the owners. The addition of the US Department of Energy grant assistance enabled the project to proceed and the project was then implemented by Woking Borough Council in conjunction with Thameswey. The Council have facilities with an assured lifetime and requirement for energy, thus removing some commercial risk to the project of the owner still using the installation for the life of the fuel cell CHP. Although the Council’s track record in sustainable energy provided confidence in the sponsors of the project, it still took two years to reach the point where installation work could commence. To enable the project to proceed dilution economics was applied by combining the fuel cell CHP into a larger trigeneration scheme to compensate for the commercial risk of this relatively (in UK terms) unproven technology. The dilution of the fuel cell CHP in capacity terms was approximately 6:1.

The implementation of the project owes much to the nature and commitment of Woking Borough Council with its long term and proven commitment to environmental improvement and innovative approach to project funding. There were numerous difficulties, frustrations and long delays and even with the sponsorship of the fuel cell CHP purchase, the economic justification would have been far less easy to argue with funders had the fuel cell CHP been proposed on a stand-alone basis, rather than as part of a much larger trigeneration project.

3.3 Project Cost

The total capital and installation costs of the fuel cell CHP element only of the project is £1,047k. The replacement of the fuel cell stack at 40,000 hours is included within the maintenance costs.

The breakdown of the financial support can therefore be summarised as follows:

The Department of Trade and Industry	£ 175,215
Advantica Technologies Ltd	£ 150,000
Woking Borough Council/Thameswey Energy Ltd	£ 578,699
US Dept. of Defence via US Dept. of Energy	£ 142,860 (@ $1.40/£)
	£1,046,774

In addition, the Energy Savings Trust Residential CHP Programme grant of £125k was awarded to the Council for the element of Phase 2 that would enable surplus power from Phases 1 and 2 to be exported over public wires to sheltered housing residents under the Exempt Licensing regime.

3.4 Project Timescales

The project timescales were as follows:-

Exploratory meeting	5 March 1998
Conceptual design	Mid 1998
Consortium established	2 December 1998
OJEC advertisements	December 1998
Pre-tender expressions of interest	December 1998
Approval for DTI support	25 February 1999
Tender specification	July 1999
US Fuel Cell Climate Change Grant	9 July 1999
First Planning approval	3 August 1999
UTC (IFC) Fuel Cell Contract let	14 May 1999
First Installation Tender exercise	September 1999
Second Installation Tender exercise	November 1999
Tender Evaluation	December 1999
Balance of funding established	28 February 2001
Turnkey Contract let	28 February 2001
Second Planning approval	23 May 2001
Installation Contract let	10 August 2001
Fuel Cell Inspection at UTC (IFC), USA	16 August 2001
Delivery to site	15 October 2001
Testing and commissioning	21 December 2001.

The extended timescales, particularly during 2000, indicated the degree of effort required to achieve a ground-breaking project of this type in the UK. Delays resulted, in part, from the cost implications of a significant US dollar exchange rate change and a second planning application that was required for to revise the location of the fuel cell CHP and to reduce costs to within the project funding.

3.5 Thameswey

In the UK local government finance is strictly controlled by Central Government and the Council does not have the same flexibility as private sector organisations in determining its capital and revenue budgets. Hence the need to form a public/private joint venture ESCO, to procure private finance and realise the Council's energy and environmental objectives. The Council cannot achieve these solely through its own resources even though it has responsibilities under Local Agenda 21, the Home Energy Conservation Act, the Local Plan, Environmental, Social and Economic Well-Being Policies under its Community Plan, etc. In addition, the Local Authorities (Companies) Order 1995 states that Local Authorities cannot invest more than 20% in private companies, otherwise the private company would be treated as a Local Authority controlled company and be limited by Central Government's capital controls.

As part of the UK Department of the Environment, Transport and the Regions funded Energy Saving Trust ESCO Programme, the Council obtained leading counsel's opinion on local authority vires with respect to forming or participating in ESCO's. The outcome of this work was the formation of the UK's first EESCO and ESCO, called Thameswey, to take forward the innovative and unique green energy services concept that Woking Borough Council had so successfully employed over the last 10 years at a small-scale level using local authority finance to a large-scale level using primarily private finance. The Council owns the intellectual property in Thameswey and the Thameswey registered trademarks.

Thameswey Ltd., is an Energy and Environmental Services Company or EESCO wholly owned by Woking Borough Council which enters into public/private joint ventures to deliver its energy and environmental strategies and targets (primarily green energy, tackling fuel poverty, water, waste and green transport). The local authority vires and the Memorandum of Articles and Articles of Association of the EESCO enables Thameswey Ltd., to participate in energy services projects both inside and outside the Borough of Woking.

Thameswey Energy Ltd., is a public/private joint venture Energy Services Company or ESCO between Thameswey Ltd., and ESCO International A/S owned by Miljo-Sam Holding APS. Miljo-Sam Holding APS is owned by Pen-Sam (a Danish pension fund) and Hedeselskab who also own Hedeselskabet Miljo og Energi A/S, a Danish green energy company. Projects are financed with shareholding capital and private finance with project development carried out jointly between the Council and Hedeselskabet Miljo og Energi A/S who also own DDH Contractors UK Ltd., who act as the turnkey contractor on large scale district energy schemes. Hedeselskab is a foundation committed to environmental projects whose patron is Her Majesty Queen Margarethe II of Denmark.

The formation of Thameswey has so far enabled the Council to increase its distributed embedded generation capacity by 750%.

Thameswey Ltd (TW), incorporated in 1999, principal objectives are:

- To promote energy efficiency, energy conservation and environmental objectives by providing energy and/or environmental services

- To develop and implement technologies for the production and supply of energy

- To produce and supply energy (and any related by-products) in all its forms

- To acquire and hold interests in the share capital or loan capital of any company or corporation and in particular in companies engaged in the energy and/or the environmental business

- To provide financial, managerial and administrative advice, services and assistance

- To make facilities and services available for its customers and customers of companies in which it holds an interest.

Thameswey Energy Ltd (TEL), incorporated in 1999 and capitalised in 2000, principal objectives are:

- To own and operate plant for the production and supply of electricity, heat and chilled water to customers and activities ancillary thereto.

- To develop and implement technologies for the production and supply of energy.

- To produce and supply energy (and any related by-products) in all its forms.

Appendix 1 includes details of TW and TEL in terms of the Agenda Item from the Policy and Resources Committee meeting on 30 September 1999, at which point approval to proceed was given. It should be noted that in respect of this Agenda Item that Difko's interest in Thameswey was subsequently acquired by HME prior to the incorporation of Thameswey.

Det Dansk Hedeselskabet or DDH Contractors UK Ltd, another company wholly owned by Hedeselskabet Miljø og Energi A/S, is the turnkey contractor for TEL projects. DDH Contractors UK sub-contract packages of work by competitive tendering which overcomes the multiplicity of tenders incurred with a conventional competitive procedure, thereby avoiding wasted effort and cost and speeding up programme delivery. It is a prerequisite of the institutional funder that the company which installs the equipment, then operates and maintains it. DDH Contractors UK was the main contractor for the Woking Town Centre CHP – Phase 1 project. However, in this instance, due to Woking Borough Council's prior procurement of the sponsorship/finance, the contract with UTC Fuel Cells and the design and procurement of the installation works, the Council completed the Woking Park – Fuel Cell CHP project as a Council project and handed over the installation to TEL on completion.

TEL is the vehicle through which Woking Borough Council invests in energy and environmental services projects. TEL project finance comprises 20% shareholding capital and 80% loan finance capital. Of the shareholding capital, 19% is provided by Woking Borough Council via TW and 81% is provided by HME via ESCO International A/S. The loan finance is also procured through HME. Thus, for every £38,000 invested by TW, the result is £1,000,000 in total project investment. The innovative funding mechanism is similar to the Council's energy efficiency recycling fund which ensures that the Council always has sufficient shareholding capital to invest in TEL projects regardless of how large the projects are.

Although the Council is a minority shareholder in TEL, it owns the intellectual property in Thameswey and the Thameswey registered trademarks. Minority shareholder's protection is also incorporated in the shareholders agreement.

Additional information can be found on the Woking Borough Council's website: www.woking.gov.uk .

3.6 Private Wire Economics

The grid supply price of electricity is made up as follows:-

- Electricity.
- Transmission Losses.
- Distribution Losses.
- Transmission Use of System (TUoS) charge. This is the fee charged by the National Grid Company for transporting the electricity from the power station to the grid supply point.
- Distribution Use of System (DUoS) charge. This is the fee charged by the local Distribution Network Operator (DNO) for transporting the electricity from the grid supply point to the customer.
- Renewables Obligation. A small levy charged to every customer for financing the UK Renewables Obligation.
- Climate Change Levy. A levy charged on all fossil fuels and centralised power generation applying to all non residential customers.
- Value Added Tax.

Customers supplied directly from good quality CHP or renewable energy are exempt from the Climate Change Levy.

The above shows what goes to make up the grid supply price of electricity but the proportions vary depending on the size of the customer (ie., the final supply price of electricity). What does not change by much is the actual price of electricity, typically 1.4p/kWh to 1.6p/kWh at current NETA rates.

Therefore, if a domestic customer or small business customer is considered the discrepancy between the actual price of electricity and the electricity supply price is the greatest whereas for a very large customer (eg., steel or chemical works) the discrepancy is the smallest (but still large in comparison with the actual price of electricity).

As an example of the domestic/small business case electricity supply prices are taken from the Seeboard (the DNO for the Woking area) region to explain the effect of transmission and distribution losses and use of system charges (plus other charges such as the Renewable

Obligation and Climate Change Levy, where applicable) to explain the financial effect of such losses and charges on the electricity supply price.

Foe Seeboard's standard tariff rates (which are banded) the first 182kWh per quarter costs 9.96p/kWh and the remainder costs 6.23p/kWh (both excluding VAT). This means that with the current grid price of 1.4p/kWh, the rest of the electricity supply price (eg., transmission and distribution losses, TUoS, DUoS, etc) costs 8.56p/kWh for the first 182kWh per quarter and 4.83p/kWh for the remainder, ie., most of the electricity supply price by far is not the actual electricity. In this case electricity represents 14% and 22%, respectively, of the banded rate electricity supply prices and the T&D losses and use of system charges plus other charges represents 86% and 78%, respectively, of the banded electricity supply prices. Similar calculations can be made for larger consumers paying for example 4.0p/kWh to 5.5p/kWh.

When electricity is exported from from CHP or renewables to the grid the most that can be paid for the electricity is 1.4p/kWh (if a licenced supplier can be found who will buy it and the NETA imbalance charges are ignored!) as all of the other costs have to be added to it to make up the electricity supply price. These charges are added to the export price of electricity even though under the laws of physics electricity will always flow to the nearest load, ie., the local community, and the exported electricity is making very little use of the distribution network and no use at all of the national grid. Essentially under the existing Regulatory regime, all CHP and renewables are treated as if they were 1,000 MW coal fired power stations in the Midlands or North of England. Therefore, the regulatory regime (in its current form) is the primary barrier to the take up of CHP and renewables as no recognition is made of the embedded benefits of CHP/renewables.

That is why Woking installs private wire and how Woking is able to supply green energy (where virtually all of the electricity supply price is actual electricity) in competition with grid brown energy (where most of the electricity supply price is not actual electricity), ie., by making use of the laws of physics. Even with ROCs (if renewable energy generators can actually obtain the 3p/kWh penalty price) it is still more economic to supply electricity from CHP/renewables directly to customers on private wire rather than to the grid.

Integrating private wire networks with district heating and cooling networks (where the infrastructure costs are already written down against the district heating and cooling mains) is cost effective since the cost of implementing private wire is a comparatively small cost in the overall cost of the district energy scheme and yet yields the greatest income.

Connection costs are also reduced since the grid only sees the surplus export (which is always designed to be less than the site import) and the in worse case scenario with the CHP or renewables not running the private wire site presents no more of a connected load to the grid than a normally connected demand site.

Island generation in the event of a failure of the grid is also possible on private wire (via black start generation) to provide security of supply to customers whereas island generation is not possible on public wires.

If the Regulatory regime was changed to recognise the laws of physics for small generators (ie., CHP/renewables of 100 MW_e or less) and the barriers to supplying domestic customers removed (currently limited to 1 MW_e [about 1,000 dwellings] over each private wire system and to 2.5 MW_e [about 2,500 dwellings] in aggregate for all of the ESCO's sites put together over public wires) a level playing field would be created between distributed embedded generation (ie., CHP/renewables) and centralised power stations. Each of Woking's sites provides standby and top up to each other under an enabling agreement for exempt supplier operation. There is no reason why this could not be replicated across the UK.

The removal of the regulatory barriers to CHP/renewables would also accelerate the achievement of the UK's Energy White Paper, Kyoto, CHP and renewable energy targets and create the local sustainable energy systems that will be needed in the future as fossil fuels run out. This would also give the UK a leading edge over other countries who do nothing about a declining fossil fuel world. The grid is only suitable for large scale fossil fuel or nuclear power stations (where power flows taper downwards against the flow of CHP/ renewables) and is therefore unsuitable for the many thousands of small scale CHP/renewables/ hydrogen generation systems that will be need in the future, which will require local active distributed embedded generation networks interconnected together throughout the UK as the Council, through its Thameswey ESCO, is building (in the form of private wire) throughout Woking.

3.7 Planning Permission

For a project of this degree of innovation, careful preparation and briefing is necessary to gain support and approval from the local planning authority. Success was aided by the fact that Woking Borough Council Members had been committed to reductions in energy consumption and CO_2 emissions that had been demonstrated for some years. However, the fuel cell CHP project raised new challenges and pushed back the thresholds of the risks to be addressed for the following reasons:-

- It was to be the first installation of its type in the UK, and would require careful evaluation for that reason alone. It was new and very different.

- Woking Park has a history of sensitive planning issues. Originally Woking had a 1970's indoor pool in the town centre, and an open-air pool in Woking Park. The new facility, built in phases in 1990 and 1992, was a major development in a green area, 400m away from Woking Leisure Centre, that was built in the 1970's.

- The Pool In The Park is constructed of translucent Kalwall panels, which appear to glow in the dark, and the Leisure Lagoon is built with sympathetic blockwork and glazing. Thus, there were concerns about spoiling the appearance, especially when the fuel cell CHP was originally to be sited in front of the building.

- There were operability and reliability questions in that the fuel cell CHP was to be run in a demanding and fully commercial environment.

- There were also health, safety, noise and emissions issues.

The original committee structure reporting to the Council, that was relevant to this project at the time, was the Policy and Resources Committee, with its Resource Management Sub-Committee to which authority had to be sought to submit a planning application for the project. In addition, authority also had to be sought from the Arts, Leisure and Tourism Committee that was responsible for Woking Park to implement the project. Following these authorities a planning application was submitted to the Development Control Sub-Committee (a sub-committee of the Planning and Environment Committee), the local planning authority.

Since the implementation of the project the committee structure has changed to an Executive system under Local Government reorganisation.

To gain approval, it was necessary for the Resource Management Sub-Committee to grant delegated authority to Council officers to submit the necessary planning application, effectively on behalf of itself. It was also necessary to seek approval from the Arts, Leisure and Tourism Committee for the location of the proposed installation, as this Committee is responsible for Woking Park as a leisure and tourism site. From the Committee's perspective, there were some initial concerns about size, visual impact, etc., but ultimately the Committee considered there were 'no downsides', the project was 'very well presented and will draw attention to Woking's achievements'.

The Development and Control Sub-Committee had some initial concerns in view of the complexity of the project, its aesthetics, environmental impact, any emissions, etc.

It was therefore necessary for all Committees and Sub-Committees to be fully briefed through the provision of drawings and detailed explanations. The second planning application which was also approved is attached as Appendix 2.

The Principal Planning Officer presented the first planning application to the Development Control Sub-Committee. There were no questions and approval was given. All three political parties spoke in support of the project and not a single objection was received from local residents or businesses. The only condition set was that noise levels should not exceed 40dBa at the nearest residential dwelling. This was to be subsequently monitored. BBC Southern Counties Radio subsequently interviewed Allan Jones MBE on the successful planning application.

The second planning application (for the location change) was presented to the Planning Committee under the new local government structure. All Committees had by then been replaced by a new Executive, with the exception of the Development Control Sub-Committee, which was replaced by the Planning Committee. Objections were raised from some local residents and detailed emissions data, (derived from DETR Good Practice Guide 116, Environmental Aspects of Large Scale Combined Heat and Power), and a supporting technical report had to be provided. Despite the objections, the Principal Planning Officer advised that the proposal met several of the key objectives of the Local Plan with regard to the encouragement of energy efficient projects and combined heat and power schemes. The Environmental Health Officer also confirmed that the emissions emanating from the proposed installation would be considerably reduced compared with the present situation, through its enhanced energy efficiency. In his terms, the proposed project was 'cleaner' than the existing plant.

In summary, there were a number of key aspects to the success of the planning process:

- It was considered to be an appropriate application for this new technology and a 'brave decision', pushing back the frontiers of experience

- There was a good working relationship within the Council officers and committees

- There was cross-party support for environmental matters and the political will, in an authority with no single dominant party

- Enthusiasm and promotion of the benefits to Woking was crucial

- It was important that the fuel cell CHP was absorbed into a larger project, giving the overall scheme a sound economic and environmental basis

- The Planning Office was sympathetic to amendments and endeavoured to delay the project to the minimum.

3.8 Supply of the Woking Park Fuel Cell CHP

The PC25 Model C fuel cell is an integrated, packaged 200 kW_e fuel cell power plant, or combined heat and power unit, manufactured by UTC Fuel Cells based in South Windsor, Connecticut, USA.

IFC, which was part of United Technologies Corporation (UTC) was incorporated into UTC Fuel Cells LLC in 2002 to combine the PAFC technology with the PEM technology and to directly link fuel cells to the main UTC brand name. UTC is a world leader in fuel cell production and development for commercial, transportation, residential and astronautical applications. It is the supplier of fuel cells for the U.S. space programme and the only company currently producing a commercially available fuel cell power plant for combined heat and power applications.

UTC Fuel Cells has commercially produced the PC25 since 1991 and has delivered more than 220 units to 17 countries on 6 continents, with recent sales to Brazil (the first in South America) and Woking (the first in the United Kingdom). The fleet has accumulated more than 4 million hours of operational experience.

The PC25C performance specification is as follows:

PC25C Performance Data

Feature	Characteristics
Rated Electrical Capacity	200 kW/235 kVA
Voltage and Frequency	480/277 V, 60 Hz, 3 phase 400/230 V, 50 Hz, 3 phase
Fuel Consumption	Natural gas: 58.0 m^3/hr @ 102-356mm water pressure Anaerobic digester gas: 90.6m^3/hr CH_4
Efficiency (LHV Basis)	87% Total: 40% Electrical, 50% Thermal
Emissions	Negligible (< 1 ppm CO, SO_x; 1 ppm NO_x)
Thermal Energy Available Standard: High heat options:	 264 kW @ 60°C 132 kW @ 60°C and 132 kW @ 120°C
Sound Profile	Conversational level (60dBA @ 9 m), Acceptable for indoor installation
Modular Power	Flexibility to meet redundancy requirements as well as future growth in power requirements.
Flexible Siting Options	Indoor or Outdoor installation, small footprint
Power Module: Dimensions Weight	3048 mm x 3048 mm x 5846 mm 18.14 tonnes
Standard Cooling Module: Dimensions Weight	1219 mm x 4367 mm x 1219 mm 0.771 tonnes

Optional Operating Modes

Option	Characteristics
Grid connected operating mode	Constant power output operation in parallel with electric grid. Automatically synchronises with the electric grid.
Grid independent operating mode	Independent, automatic operation. Output tracks the electric load.
Grid-connected/grid independent operating mode	Constant power output operation. When grid fails or is out of tolerance the PC25 automatically disconnects from the grid and provides independent operation.
Load shed	If the grid fails, the optional load shed equipment can provide a signal to isolate individual non-critical loads.
Grid-connected circuit breaker enable control signal	Enables remote disconnect of PC25 from grid.
Grid-connected/grid-independent parallel operating mode	Enables multiple PC25's installed in parallel to share load.

PC25 Power Plant Options

Option	Characteristics
High grade heat recovery	132 kW @ 120°C 132 kW @ 60°C
Double wall heat recovery heat exchanger	Domestic water applications.
Remote data acquisition and control	Remote access and control of PC25.
Choice of operating fuel	Natural Gas or Anaerobic Digester Gas.
Dual fuel operation	PC25 will automatically change from one fuel to another as required.

Fuel Consumption Rates for Rated Power (200 kW)

Fuel	Flow (m^3/hr)	Flow (kg/hr)
Natural gas	58.0	38.1
ADG with 60% CH_4	90.6	104

3.9 Installation of the Woking Park Fuel Cell CHP

Woking Park dates back to Victorian times and now contains the Pool In The Park/Leisure Lagoon swimming pool complex, Woking Leisure Centre, sports pavilions, public conveniences, park lighting, etc. The Pool In The Park was constructed in 1990, the Leisure Lagoon constructed in 1992 and Woking Leisure Centre constructed in the 1970's. The Leisure Lagoon has an existing reciprocating engine based CHP supply of 2 x 75kW$_e$, installed in 1992 as part of the construction of the new Leisure Lagoon. The complex comprises a leisure lagoon (wave machine, rapids water ride, flumes, etc), competition and training pools, changing and restaurant facilities and is open to the public for up to 17 hours per day, seven days per week. Plant operates continuously, however, to avoid problems of temperature swing and condensation damage. The Leisure Centre is about 400m distant, across the Hoe Stream, from the Pool In The Park/Leisure Lagoon complex.

Typical monthly heat and electricity consumption profiles are shown in Figures 1 and 2 for the Pool In The Park and the Leisure Lagoon. Figures 3 and 4 show heat and electricity profiles for the whole complex, with the fuel cell CHP in proportion in all cases. Energy costs are shown in Figure 5. A plant design schematic diagram for Phases 1 and 2 is shown in Figures 6 and 8 and the PC25C Monitoring Schematic is shown in Figure 7.

The fuel cell CHP installation was originally to be located outside the entrance to the Pool In The Park but, due to construction difficulties and costs, it was located to the rear of the Leisure Lagoon/Pool In The Park adjacent to the Leisure Lagoon plant room. The planning consent requires that the fuel cell be visible to the public and is therefore enclosed in an acoustic compound with a glass window. For educational purposes and for demonstrating how new and renewable energy can be integrated with other sustainable technologies, there is also a technology/information display within the viewing area. In addition, the fuel cell CHP acoustic enclosure is cladded with a technology mural covering the history of the fuel cell from when the first fuel cell was first presented by Sir William Grove in 1839, through the NASA space programme to the present time and the future of fuel cells and the Hydrogen Economy in conjunction with renewable energy and fuels.

The fuel cell CHP is part of a wider project spread over two phases. The Phase 1A fuel cell CHP project serves the Pool In The Park/Leisure Lagoon complex and Phase 2A serves Woking Leisure Centre by heat and chilled water mains and private wire, with the fuel cell operating as the lead CHP 24 hours a day, 365 days a year. The 24 hour heat load for the fuel cell CHP is a key aspect of the economic and environmental performance. The fuel cell CHP supplements the existing CHP system in the Leisure Lagoon and provides an opportunity to compare the economic, environmental and operational performance of a fuel cell based CHP with a conventional reciprocating engine based CHP.

Phase 2, through the addition of another 836 kW_e of high efficiency reciprocating engine CHP plant, will together with the solar energy photovoltaics, bring the total generation capacity to 1.2 MW_e. Surplus electricity from the combined plant is exported to some of the Council's sheltered accommodation sites, providing affordable heat and electricity to local residents as part of the Council's Tackling Fuel Poverty Strategy. The surplus export is governed by the The Electricity (Class Exemptions from the Requirement for a Licence) Order 2001 which increased the deminimus export limit over public wires from 500kW to 5MW. It was on the basis of this domestic supply that the Energy Savings Trust provided the grant of £125,000.

With the addition of the 836kW_e CHP further surplus electricity will be exported to 906 sheltered housing residents via the existing enabling agreement for exempt supplier operation. A 500kW heat fired absorption chiller (rated at 750 kW to down rate the flow rates and minimise the size of the pumps) located in the fuel cell CHP enclosure currently provides cooling to the Pool In The Park/Leisure Lagoon complex and Woking Leisure Centre.

Due to project difficulties and delays with Phase 2, which would have delayed Phase 1 still further, the Council decided to proceed with the fuel cell CHP element of the project in its revised location in advance of Phase 2. Due to flood plain issues that needed to be resolved at the Leisure Centre, Phase 1 was split into Phases 1A and 1B and Phase 2 is now split into Phases 2A, 2B and 2C. Phase 1A comprised the fuel cell CHP and Phase 1B comprised the heat fired absorption chiller, other cooling works in the Pool In The Park/Leisure Lagoon and the photovoltaics. Phase 2A comprises the Pool In The Park/Leisure Lagoon private wire district energy system between the Pool In The Park/Leisure Lagoon and the Leisure Centre, the thermal store and cooling works in the Leisure Centre, Phase 2B comprises the 836 kW_e CHP in the Leisure Centre and Phase 2C comprises the installation of local private wire networks to 906 sheltered housing dwellings and new community heating to 136 dwellings (over 78 remote community heating sites in total) to enable affordable energy (heat and electricity) to be provided to local residents. Phases 2B and 2C are currently under construction.

The fuel cell CHP system supplies low grade heat to the swimming pool hot water system, high grade heat to the district heating system, chilled water to cooling and air conditioning systems, via the heat fired absorption chiller, electricity and potentially 100% pure water via the proposed water recovery system. As water from a fuel cell has never been recovered in this way before (other than in spacecraft) it will be subject to quality analysis prior to utilisation.

The existing boiler plant in the Leisure Centre is in good condition and will be retained for standby and top up.

This project will also address some of the site's long-standing environmental issues:-

- The need for new, environmentally friendly chilled water supplies to the Pool In The Park and separate cooling and control for the Pool Hall and Spectators' Gallery, thus providing thermal comfort to swimmers and spectators

- The provision of new environmentally friendly chilled water supplies to the Leisure Lagoon, including a new supply to the existing air conditioning system in the café/bar

- The provision of new environmentally friendly cooling to the main areas of the Leisure Centre, including new chilled water supplies to the existing air conditioning systems in the restaurant, bar and crèche, and conversion of existing air handling units to provide heating, ventilation and air conditioning to the main sports halls and other areas, enabling the centre to provide thermal comfort all year round and an enhanced service to its customers.

The reduction in CO_2 emissions and the displacement of all CFC, HCFC and HFC refrigerants used by existing air conditioning systems will make a significant contribution to the Council's Climate Change Strategy for Woking.

3.10 Project Specification and Tendering

A synopsis of the specification for the engineering works involved in the project is included in Appendix 3.

The Health and Safety Executive (HSE) had no previous experience of relevant safety and hazard assessments for fuel cells and looked to the Council for guidance on how to proceed. The American Gas Association (AGA) Requirements for Fuel Cell Power Plants No. 8-90 was used as a basis for HSE approval. Similarly, the Environmental Health Officer had no guidance notes for noise but could look to US Environmental Protection Agency if there were concerns but, in the event, there were not.

The approach taken was compliant with the UK Construction, Design and Management Regulations 1994. Potential problems were identified at the specification stage but in fact only amounted to the need for blast wall protection for externally stored nitrogen cylinders. Issues concerned with the fuel cell CHP itself and other components within the UTC Fuel

Cells package were deemed to be the supplier's responsibility from the health and safety perspective. No questions or issues were subsequently raised by the HSE.

The contract specifies compliance with the UK Health and Safety at Work Act 1974, the Management of Health and Safety at Work Regulations 1992, the Construction (Working Places) Regulations 1966, the Control of Substances Hazardous to Health Regulations 1988, the Electricity at Work Regulations 1989 and the Construction (Design and Management) Regulations 1994. The Contractor is also required to comply with the Council's Health and Safety Code of Practice - Duties of Contractors.

The health and safety plan, which formed part of the tender, included the following:-

- Architect's risk assessment and designer's hazard identification sheets
- Civil engineer's risk assessment and designer's hazard identification sheets
- ONSI PC25C product description
- ONSI PC25C installation manual
- ONSI PC25C installation manual supplement: High Grade Heat Option
- ONSI PC25C installation manual supplement: Grid Independent Electrical Output Option
- AGA Requirements for Fuel Cell Power Plants No. 8-90.
- The hazardous construction materials identified included the fuel cell phosphoric acid, nitrogen and hydrogen gas.

The Council's Building Services Manager was appointed as the Planning Supervisor.

The Council's Building Services Manager was also appointed as the Project Coordinator, acting on behalf of TEL and had a key role to play working with the turnkey contractor and others. In terms of health and safety, the Planning Supervisor's role was to develop the pre-tender documentation under the Construction (Design and Management) Regulations 1994. In addition, the Project Coordinator/Planning Supervisor progress-chases the delivery of the programme, brokers arrangements and ensures that all the contractual obligations and safety regulations are complied with, before signing-off each stage of the project. This way of working proved to be very successful on Town Centre CHP project. In total 15 to 20 Council employees are/have been involved with the project at various stages.

The form of contract was M&E led and was based on the UK Standard Form of Building Contract with Contractor's Design, Joint Contracts Tribunal 1998.

3.11 Installation Procedures

3.11.1 Scope of the Contract

The scope of the work made provision for the design and installation of the fuel cell CHP, which included the collection, transportation, importing, off-loading, and delivery of the unit, along with the clearance of the site. Also included was the design and construction of a supporting ground slab (including piling) to accommodate the fuel cell CHP, absorption chiller (Phase 1B) and the associated cooler and engineering services. The design and construction of the fuel cell CHP services comprised:-

- the low grade heating system
- the high grade heating system
- the cooling system
- the acoustic enclosure arrangements
- the electrical installation, making provision for the fuel cell CHP to operate both in the grid connected and grid independent modes
- the building energy management system
- control and monitoring equipment and facilities (including RADAR)
- the fuel cell CHP gas, nitrogen and water services.

3.11.2 Delivery of the Fuel Cell CHP

The fuel cell CHP is approximately 5.5m by 4.6m by 3.0m (18ft by 15ft by 10 ft) and weighs approximately 22 tonnes unpacked. When crated it is approximately 0.6m (2 ft) larger on each dimension and approximately 2 tonnes heavier.

The design and construction contract made the Contractor responsible for the on-loading of the fuel cell CHP from the storage facility in the US, its crating-up, shipping, importing and unloading in the UK and insurance of the unit throughout its journey. To ensure that there were no problems on arrival with crossing the bridge within Woking Park (with a notional 20 tonne limit) a long wheel based vehicle was used for transport, thereby ensuring only one set of wheels was on the bridge at a time.

The value of the fuel cell CHP exceeded most lifting companies insurance limits for any one item lifted and therefore special cover was required.

The fuel cell CHP is an unbalanced load and if inappropriate slinging mechanisms were used damage could be caused to the unit. Consequently all companies involved in transporting it were informed of the correct procedures.

The import duty for the fuel cell was deliberated upon for some time and eventually it was determined that the duty rate for the unit was equivalent to that of a heat exchanger at 1.7%.

Due to the width of the unit when packed a police escort was required from the UK docks to the site address. The main reason for this was that it was wider than a standard single carriageway. A low-slung trailer accommodated the height. The costs of the escort were included within the budget.

3.11.3 Ground Floor Slab.

The ground floor slab was designed by the approved structural engineer and the installation of the piling and slab was completed by an approved sub-contractor.

The ground floor slab (11m by 9m) was designed to support all of the plant and equipment in addition to the acoustic fencing and associated services. Due to the quality of the ground, which is of a poor, sandy nature, twelve 10m by 300mm diameter sleeved piles were required to support the base. This type of piling has been used for all other local buildings.

3.11.4 The Low and High Grade Heating Services.

The fuel cell CHP manufacturer, UTC Fuel Cells, does not produce a specific design performance for the unit's services and output, including the electrical generation efficiency. UTC Fuel Cells provides a graphical representation of the useful heat output for the low and high grade heat and provides details of a minimum flow rate through the various circuits in order to maintain the fuel cell CHP in operation. The establishment of temperature differences must therefore, be made by the customer.

Therefore, the final determination of the design for the high and low grade heating system has been completed by the installation contractor as required by of the project specification.

The finalised design criteria was determined, as follows:-

High grade heat output	132 kW
High grade flow from the fuel cell	82°C
High grade flow to the fuel cell	71°C
Design Flow Rate	2.86 l/s
Design pressure drop through the fuel cell	71 kPa
Low grade heat output	112 kW
Low grade flow from the fuel cell	60°C
Low grade flow to the fuel cell	40°C
Design Flow Rate	1.33 l/s
Design pressure drop through the fuel cell	35 kPa

These figures are at a notional 200kW electrical output and a gas flow-rate of 85m^3/h.

The high grade heating services is used to pre-heat the district heating system return water and the low grade heating is used to pre-heat the domestic hot water service. There were no complications concerning the fuel cell CHP high and low grade services connections. They were installed in copper distribution pipework systems and connected to the heating and domestic services by means of separate heat exchangers.

Electricity, natural gas and water meters are installed on both circuits in order to quantify the energy and water production and performance of the fuel cell CHP.

3.11.5 Acoustic Fencing Wall

In order to comply with planning consent noise conditions a 3m high acoustic fence wall was erected around the perimeter of the external slab. The acoustic panels are 75mm deep and are constructed from a solid galvanised sheet steel outer skin and a perforated sheet metal inner face, retaining heavy density mineral wool in-fill. The exterior face of the panel system is finished with a 2-pack epoxy pain and the fencing system is supported by a galvanised steel work structure.

The acoustic performance of the fence relies heavily on the reduction in-line of site noise. The noise reduction achieved by the enclosure is 15dBa – 20dBa at a distance of 10m, provided the measuring position is not more than 1.5m above the base level chiller.

3.11.6 Electrical Installation

The electrical installation was completed in accordance with the design requirements as set and determined by the UTC Fuel Cells installation manual.

The specification required two separate electrical connections at the fuel cell CHP, comprising grid-connected and grid-independent circuits. The grid-connected circuit is used for powering up the unit and receiving power from it when the system is functioning in parallel with the grid. This circuit is fitted with metering to measure the energy generated by the fuel cell CHP.

The grid-independent circuit only operates when the grid supply fails. This circuit enables the site to receive a 200kW supply from the fuel cell CHP in island generation mode when the grid has failed. In these circumstances, the maximum amount of power demand on site cannot exceed 200 kW. A load-shedding device installed on the power circuit from the Pool In The Park/Leisure Lagoon to Woking Leisure Centre prevents the connected load exceeding 200kW in island generation mode. The entire Woking Park site will be enabled to run in the grid-independent or island generation mode when the Phase 2B - 836kW$_e$ CHP has been installed in Woking Leisure Centre currently under construction and scheduled for completion in March 2004. The 836kW$_e$ CHP includes an integral island generation mode operation in the event of a failure of the public grid. The design of the system in such that the 836kW$_e$ CHP island generation mode operation will be black-started by the fuel cell CHP.

The two existing 75kW$_e$ CHP units are electrically interlocked to prevent their operation when the fuel cell CHP operates in grid-independent mode. The reason for this is two-fold. Firstly the 75kW$_e$ CHP manufacturer has not approved the fuel cell CHP as a black start generator. Secondly, the energy provided by the existing CHP plants cannot be regulated by the site demand, they simply operate at full electrical output. Further work will be needed to adapt these CHP units to operate in island generation mode, as follows:-

- Approval from the manufacturer to run these CHP units in island generation mode.
- The site connected load would have to be assessed to ensure that the site demand accurately meets the site generating capacity and the load is interlocked with the CHP units to prevent their operation if this was not the case. This would prevent the fuel cell CHP from being connected to a higher site demand than it can meet.
- A further motorised circuit breaker would be required to prevent energy transfer to the network in this mode.

However, since the Woking Park site maximum demand is 750kW$_e$ and this can be met by the combination of the 200kW$_e$ fuel cell CHP and 836kW$_e$ CHP it is not necessary to reconfigure the two 75kWe CHP units to island generation operation at this stage. This will be reviewed when the Woking Park CHP network is extended to a nearby housing estate.

In the absence of any specific directive for the connection of fuel cell CHP to the local distribution network (public grid), the operating characteristics have been set to meet the standards specified in the UK Electricity Association's Engineering Recommendations G59/1. This document strictly applies only to generation under 5MW and connected at 20kV or below. However, the same protection is usually fitted for all embedded generator connections. See Department of Trade and Industry ‘A Technical Guide to Connection of Embedded Generators to the Distribution Network: ETSU K/EL/00183/REP’ 1999.

In the case where the local distribution network (public grid) goes outside of limits of the fuel cell CHP the fuel cell CHP will go into Idle operation. Reference to the fuel cell CHP manual provides more specific information on its operating characteristics in this mode.

3.11.7 Building Energy Management System Control and Monitoring

The building management (BEMS) and monitoring system has been designed in accordance with the requirements of the DTI (Advantica Technologies) monitoring specification and those of the mechanical installation design. The details of this design are contained within a specific volume of the specification, which provides all relevant information.

The Advantica Technologies monitoring panel is not connected to the BEMS network on site and has a dedicated telephone line and modem facility for monitoring of the fuel cell CHP. No control facilities for the fuel cell CHP are linked to this panel.

The mechanical services control panel is linked to the site BEMS network and can be accessed via the site supervisor.

3.11.8 Fuel Cell CHP Natural Gas, Nitrogen and Water Supply

The fuel cell CHP is connected to the site natural gas supply and the design gas flow rate is $85m^3/h$.

The fuel cell CHP nitrogen supply comprises four bottles for standby use and four bottles continuously on line.

The fuel cell CHP is connected to the mains water supply and utilises this water above the balance point temperature. The quality of water from the mains supply water must be high and the supply therefore, draws from a de-ionised water supply bottle to reduce the conductivity of the water.

The conductivity of the mains water supply on site is approximately 650 μSiemens, which reduces to approximately 1 μSiemen following the blending with the de-ionised water.

The water supply to the fuel cell CHP is only required when the ambient temperature exceeds 27°C (the balance point temperature) and the supply rate under these conditions is approximately 1.2 litres per minute. At lower temperatures condensate from the fuel cell exhaust is re-cycled. The capacity of the installed de-ionised water bottle is 2200 litres. At temperatures above an ambient of 27°C, the de-ionised water bottle will require replacement every month.

The water is treated further inside the fuel cell CHP to reduce the conductivity level and to improve the water quality still further.

3.12 Import Duty and VAT

No classification currently exists for a fuel cell CHP and it was originally listed as a boiler at an import duty of 2.7%. After negotiation with HM Customs & Excise it was re-classified as a heat exchange unit at an import duty of 1.7%. The correct classification therefore is 'Chapter 8419 Classified Heat Exchange Unit'.

In addition, HM Customs & Excise advised that import duty was only payable on the cost to the customer in the UK and that the US Fuel Cell Climate Change grant can be deducted, import duty only being payable on the net cost of the fuel cell CHP plus shipping into the UK. This reduced the import duty from £20,245 to £8,541.

VAT is also payable on the net cost of the fuel cell CHP when it is delivered into the UK and it was not released from the docks until the import duty and VAT had been paid.

Import duty educational relief can only be claimed by the Council after installation. Arrangements will be made with HM Customs & Excise to inspect the site to determine the use in relation to the research, development and educational aspects of the project.

As no export/import facilities are provided by the fuel cell CHP manufacturer under the supply of the fuel cell CHP contract the collection of the fuel cell CHP from the USA, shipping, import duty (and VAT) and delivery to site had to be included in the installation contract.

3.13 Factory Acceptance Tests and Inspection

The delivery of the fuel cell CHP under the fuel cell CHP supply contract with UTC Fuel Cells is effectively its collection from their premises in the USA. It therefore, became necessary to include the shipping, freight, import duty (and VAT) and delivery to site in the installation contract. In order to protect the Council's interest in paying 90% of the contract price before collection of the fuel cell CHP, testing and inspection at UTC Fuel Cells works were also included in the installation contract. The acceptance test certificate for the fuel cell CHP was submitted with the Council's claim for partial payment on 27 September 2001.

Note: When making arrangements to transport the fuel cell CHP from UTC Fuel Cells works, it became apparent that the weight distribution was extremely uneven, necessitating the purchase of several additional lifting eyes at £50 each. This was not specified in any UTC Fuel Cells manual and had therefore, not been planned for.

3.14 UTC Visit - Technical and Future Commercialisation Issues

The Council and the installation contractor's visit to UTC Fuel Cells in the USA on 15 and 16 August 2001 also provided the opportunity to raise technical and future commercialisation issues with UTC Fuel Cells management. These meetings were held with Rick Wallace (Customer Support), Linda Boyd (Customer Support), Herb Healy (Manager, Programs) and Joe Staniunas (Manager, Installation Projects). Information from the visual inspections and discussions held at UTC Fuel Cells is attached as Appendix 4. Some of the points which emerged were as follows-:

- Market demands have meant that the thermal output of the Unit has been increased from what was 205kW to between 264kW and 293kW (700,000BTU/h and 1,000,000BTU/h).

- The PC25C has considerable potential as a black start generator, owing to its extremely rapid response rate, compared with conventional diesel standby sets.

- UTC Fuel Cells showed considerable interest in Woking's proposals for water recovery or recycling.

- Costs for stack replacements through UTC Fuel Cells are of the order of $300 000. Other approved suppliers, such as Sure Power, are now entering the market with replacement costs at $175 000. Re-conditioned stacks are also available.

- UTC Fuel Cells are now developing a PEM fuel cell for light commercial/domestic and transport applications. They are also developing a PEM in the range 150 – 200kW, to be known as the PC35, at a target price of one third that of the PC25.

3.15 Commissioning and Operation of the Fuel Cell CHP

3.15.1 Overview

The multi phase Woking Park CHP scheme for the Pool In The Park, Leisure Lagoon and Woking Leisure Centre comprises several elements including CHP, fuel cell CHP, photovoltaics, thermal storage and heat fired absorption cooling. These primary energy systems are interconnected together by private wire, heat and chilled water mains distribution networks which run between the three primary building complexes. The first phase covered the primary energy works at the Pool In The Park/Leisure Lagoon and is split between the fuel cell CHP installation and commissioning, including linking its heat supplies into the existing heat mains at the Leisure Lagoon (Phase 1A) and the installation of the heat fired absorption chiller and the conversion of cooling/air conditioning systems at the Pool In The Park/Leisure Lagoon to use the heat fired absorption cooling chilled water (Phase 1B).

Phase 2A completed the thermal store, private wire district energy networks between the Pool In The Park/Leisure Lagoon and Woking Leisure Centre and the conversion of air conditioning systems at Woking Leisure Centre to use the heat fired absorption cooling chilled water. Phase 2B, currently under construction, is the 836kW_e engine-based CHP system in Woking Leisure Centre and Phase 2C is the supply of surplus export power from the Woking Park CHP system to 906 dwellings at 66 existing and new community heating installations of various sizes and locations around the Borough of Woking.

The testing and commissioning on completion of the construction phase of the fuel cell CHP was carried out by UTC Fuel Cells and 10 working days for this element of the work was included in the UTC Fuel Cells contract. However, the actual commissioning period was 15 working days because of the need to install the grid independent system. The fuel cell CHP was commissioned as soon as the Phase 1 installation works was completed sufficiently to enable the fuel cell CHP to operate and provide energy to the district energy system. The initial commissioning of the PC25C took place over a 3½ week period – extended from that actually required to allow for the upgrades and modifications to be installed, for the Christmas break and for the unexpected need for the commissioning engineer to return to the United States. Following initial commissioning, there was a period of 'settling in' issues which delayed the acceptance of the fuel cell CHP by the Council.

3.15.2 Preparation for Commissioning

The manufacturer of the fuel cell CHP issued a pre-commissioning check list which clearly identifies the manner in which the installation had to be presented before the commissioning engineer attends. The pre-commissioning check list also included information concerning the start up consumables that must be present on site in order for the commissioning to be completed. This includes glycol for the cooling circuit and nitrogen for the fuel cell system along with charcoal and nuclear resin for the water treatment system. Once the installation is complete and the consumables on site the start up procedure takes approximately 10 working days to complete.

The most important elements of the preparation are the long lead time items that must be in place before commissioning can be undertaken. These elements were:-

- Booking the commissioning engineer from the UTC Fuel Cells for the predicted date of commissioning. This was being considered by late September 2001, 3 months before the planned commissioning date.

- A commissioning plan, ie., details of what services must be in place and what isolations of host services are required. These were communicated to the installers and operators of the host facility and any constraints identified.

- Training of operational staff. Although the commissioning engineer was in charge of the fuel cell CHP in the initial start-up process, once operating, knowledgeable on-site staff were required to deal with any teething troubles and routine operational issues. UTC Fuel Cells run a 4 day course for operators and 2 of the installation contractor's engineering staff (1 mechanical engineer and 1 electrical engineer) were trained prior to the commissioning. The installation contractor continued to operate the fuel cell CHP until the fuel cell CHP system was handed over to Thameswey Energy Ltd (TEL). Two further engineers from TEL's maintenance contractor were trained later.

In addition to the longer lead items other items were also made ready in the period shortly before the commissioning began, as follows:-

- Refining the commissioning plans to allow for shifts in expected completion of associated services.

- An ample supply of bottled nitrogen to cover both the commissioning requirement and the possibility of a number of start-ups and shut-downs during the commissioning period. UTC Fuel Cells recommended at least 12 extra bottles for commissioning (normally 8 are available to the fuel cell CHP – 4 on-line and 4 on stand-by). The installation contractor arranged for 16 extra bottles to be provided on site. The extra bottles were all used in a relatively short time and were rapidly removed from site after use for maintenance of site safety.

- Weatherproofing of the control module area. During commissioning constant access was required to the control system. The access panel is fitted with a drop-down shelf for mounting the laptop computer used for manual commissioning control (known as LDT – local data terminal). This area is subject to rainwater falling from the top of the fuel cell CHP casing, which can damage the laptop computer and slow down commissioning if no method of shelter is provided.

- UTC Fuel Cells operate a process of continuous improvement based on their operating experience with 300+ other installations and various upgrades had been specified since the Woking PC25C had been built. In addition, the PC25C had been packed without the ‘grid independent’ module. Thus, sufficient extra time was allowed in the commissioning plan for these additions and upgrades (retrofit kits) to be installed.

The final plan for the site was to commission the fuel cell CHP prior to the Christmas break 2001. As the services for the off-take of heat from the PC25C were only expected to become available late in the commissioning period (completion of control systems), all heat was to be dumped initially using the fuel cell CHP associated air cooler. The UTC Fuel Cells commissioning engineer arrived on site on 5 December 2001 and the commissioning was completed on 21 December 2001.

3.15.3 Commissioning Procedures

The PC25C has 4 principal operating modes:-

- ENERGISED OFF – the fuel cell CHP is not generating, but its coolant system is circulating to protect systems from frost using internal heaters drawing external power.

- IDLE – the fuel cell CHP is running, but only generating enough power for its own internal systems including, freeze protection.

- GRID CONNECT – the fuel cell CHP generates up to 200 kW in excess of its own requirements (~30 kW at full load) and synchronises with an external grid.

- GRID INDEPENDENT – the fuel cell CHP will modulate to follow local loads in the absence of an external grid and will provide synchronisation for other generators on its local grid (ie., island generation on the private wire network).

The UTC Fuel Cells commissioning engineer completed the start up procedure although a trained operator was required to work with the engineer to complete the tasks as certain elements are double-handed.

Immediately upon start up the fuel cell CHP was continuously monitored and the dial out facilities of the fuel cell CHP responded to by a competent engineer. In order to facilitate this requirement, two engineers were sent to the United States to complete the operators' course prior to the start up procedure commencing on site. The two engineers were familiar with the fuel cell CHP having worked with the start up engineer on site and were capable of maintaining its operation.

As with all complex plant, commissioning of the fuel cell CHP followed a set procedure. The standard procedure for the PC25C included filling the circulating systems with fluids, verifying the operation of each module and testing of the motors, pumps and valves. A summary of the major process and time intervals for the initial start-up of the fuel cell CHP is detailed in the table below.

Drying fuel cell stack using flow of nitrogen on anode side and air on cathode side – the stack is wetted in the factory to prevent crystallisation of phosphoric acid during shipping	7 hours.
Reduce shift catalyst by manual control of feed gas rates	3 hours
Stand in IDLE mode while conducting system checks	1 hour

Ramp fuel cell output up in 25% stages while checking tuning of reformer operation	12 hours
Test GRID CONNECT to GRID INDEPENDENT mode switching – this requires interruption of grid supply and must be performed in liaison with the host site.	2 hours

A timetable of the main events in the commissioning of the fuel cell CHP at Woking Park is detailed in the following table. This table also details the problems that were encountered and the resolutions of the problems to keep the commissioning on schedule.

Date	Activity
5-12-01	Commissioning engineer arrives
6-12-01	Install 'grid independent' board and filtering equipment, fill water treatment bottles with resin.
7-12-01	Power available to fuel cell. Fill and flush pipe-work lines. Fill system with glycol and deionised water as appropriate. Achieved ENERGISED OFF mode
10-12-01	Commissioning engineer returns to USA, process suspended.
19-12-01	Commissioning engineer returns to site. Fault found in low grade heat pump controller – swapped with high grade heat controller (fuel cell can operate on low grade heat off-take only). Begin drying fuel cell stack.
20-12-01	Complete drying stack, purge cathode with nitrogen. Attempts to update system software by telephone from IFC HQ experienced difficulties – possibly due to faults with rain affected laptop.
21-12-01	Software problems resolved. Reduced shift catalyst. Entered local gas data. Started up fuel cell and conducted initial tuning tests at 100kW. Left operating at 200kW.
Christmas holiday	Fire brigade were called to respond to 'smoke' from the fuel cell compound. This was the normal vapour plume visible on colder days.
27-12-01	Conducted tuning tests at 50, 100, 150 and 200kW output.
28-12-01	Conducted grid independent test. Fuel cell modulated to support local load of 90kW when grid isolated by shut-down after 6 minutes. Shut-down caused by additional motor load of 90kW in the Pool systems. See notes below. On grid reconnect, fuel cell did not return to GRID CONNECT mode. Fault in connection of cables to 'grid independent' board. Further software problems. Fuel cell shut down.
29-12-01	Cable connections corrected. Software problem fixed with new download from UTC Fuel Cells HQ. Fuel cell restarted at 200kW.
31-12-01	GRID INDEPENDENT mode disabled in software until solution to loading problem found. Commissioning engineer leaves site with fuel cell running normally at 200kW.

There was no prior information on the response of the fuel cell CHP to sudden load changes in GRID INDEPENDENT mode. It was subsequently revealed that the fuel cell CHP had a programmed limit of 80kW load changes. Larger load changes would be considered to be a short circuit or fault in the local grid and the fuel cell CHP shuts down as a protective measure. As the Pool In The Park/Leisure Lagoon has at least one 90kW motor that could be used during grid independent operation, some solution to this problem was required. In view of the impending installation of the Phase 2 836kW$_e$ CHP system, it was decided to reconsider the step load issue following completion of Phase 2.

The replacement controller for the high-grade heat pump was fitted in early January 2002 and the high grade heat off-take successfully commissioned.

3.15.4 Operation

Although the fuel cell CHP operated smoothly when the UTC Fuel Cells commissioning engineer left the site, teething troubles began to affect the PC25C during January 2002 which delayed the fuel cell CHP being finally accepted by the Council. The table below documents the principal issues experienced.

Date	Problem	Resolution
Late December	Motor failure in air cooler.	Motor removed repaired and water-proofed.
5, 12 & 19/1/02	Fuel cell shuts down unexpectedly.	Fault traced to grid interference affecting cards in control system. Replacements for one and then both cards supplied by UTC Fuel Cells and new software downloaded.
23/1/02	High water conductivity alarm shuts down fuel cell.	Water treatment resin exhausted after 500 hours operation (normally a 6 month supply). Traced to the water top-up control valve allowing a small continuous flow. Valve repaired and new resin ordered from UK supplier, loaded into bottles on 26/2/02. Fuel cell back on line by 1/3/02. Discussions with UTC Fuel Cells on supply of spare bottles and why such low conductivity required in water feed to whole fuel cell system.
2 & 3/3/02	Spurious untraced trips	No action possible as no information recorded by control system.
4/3/02	Further trips identified as over-voltage alarms	Fuel cell tripping on >10% of internal voltage of 400V (tripped at 442V). Supply tolerance is +10% of 415V, ie., up to 456V. Consulted with UTC Fuel Cells regarding changing set-point in control software. Restarted fuel cell on 13/3/02.
13/3/02	Failure in control system's UPS during start-up.	New UPS ordered immediately and arrived 18/3/02. Fuel cell restarted 21/3/02.
3/4/02	Another motor failure in the air cooler.	Complaint raised with UTC Fuel Cells who arranged with their supplier to provide waterproof replacements for all 4 air cooler motors.

In general and given that this is the first installation of a fuel cell CHP in the UK, the problems encountered since the commissioning are typical of "normal" teething problems for any new plant. Most trips were associated with tuning the fuel cell CHP control system settings to the characteristics of its local electricity supply grid. Just two other failures, a faulty valve and the UPS failure accounted for the remaining periods of down time in the first three months of operation.

Following the initial 3 months teething problems/settling-in period the fuel cell CHP has proved to be the most reliable, in terms of limited down time and operational performance, of all of the CHP plants in Woking as evidenced by the high CHPQA Quality Index that the fuel cell CHP has achieved in its first year of full operation. See EXPERIMENTAL (PART 2).

4. EXPERIMENTAL, RESULTS AND DISCUSSION (PART 2)

4.1 Economic Performance

The economic performance of the fuel cell CHP in comparison with the conventional UK fuel supply and conventional CHP is detailed in this section. The UK fuel supply is taken as the benchmark which attracts the UK Climate Change Levy of 0.43p/kWh for centralised power station electricity and 0.15p/kWh for natural gas supplies. Good quality CHP and renewable energy is exempt from the Climate Change Levy.

Energy Services contracts include both the energy and maintenance costs of the primary energy plant. Hence, annual energy and maintenance budgets are used for the project economics calculations and applied to all of the primary energy plant in the Pool In The

Park/Leisure Lagoon plus standby and top up electricity from the grid and standby and top up heat from the boilers.

Woking Leisure Centre has been excluded at this stage but with the completion of the 836kW$_e$ CHP in Woking Leisure Centre all standby and top electricity from the grid will be displaced as the Woking Park site becomes self sufficient in energy and a net exporter of electricity to sheltered housing customers around the Borough.

4.1.1 Project Economics for the 200kW$_e$ Fuel Cell CHP

Capital Costs	**£1,046,774**

Pool In The Park Energy and Maintenance Budgets, Annual

Electricity	£	145,621
Woking Park Lighting Electricity	£	7,900
Gas	£	45,349
Plant Maintenance. (inc. existing CHP)	£	20,853
	£	219,723

Energy Services Budget		£	219,723
Export Income from Housing	368,229 kWh @ 5.8p/kWh	£	21,357
Climate Change Levy Exemption	1,629,360kWh Elec. @ 0.43p/kWh	£	7,006
	2,530,300kWh Gas @ 0.15p/kWh	£	3,795
		£	**251,881**

Pool In The Park Energy and Maintenance Expenditure

Fuel Cell CHP Gas	4,553,010 kWh @ 0.936p/kWh	£	42,616
CHP Gas	2,855,635 kWh @ 0.936p/kWh	£	26,729
Boiler Gas	205,345 kWh @ 0.936p/kWh	£	1,922
Availability	500 kVA @ 2.7p/kVA x 365 days	£	4,930
Fixed Charges	£2.33 per day x 365 days	£	850
Import Electricity	80,950 kWh @ 4.14p/kWh	£	3,350
	101,368 kWh @ 2.38p/kWh	£	2,410
Existing Primary Energy Plant Maintenance (inc. CHP)		£	20,853
Fuel Cell CHP Maintenance		£	28,100
		£	131,760
Fuel Cell Stack Replacement		£	31,500
		£	**163,260**

Simple Payback

Annual Savings	=	£251,881 - £163,260
	=	**£88,261 pa**
Simple Payback	=	£1,046,774 / £ 88,261
	=	**11.8 Years**

Internal Rate of Return = **8.5%**

The fuel cell CHP operates 24 hours a day, 365 days a year and has an assumed availability of 93%. Efficiency of boilers is 85%.

The payback of 11.8 years (IRR 8.5%) compares with the payback of the existing 150kWe conventional CHP system which had a payback of 3.6 years. The payback shown for the fuel cell CHP relates to this project, with a capital cost of £1.05m. For other projects, it should be remembered that the base point, i.e. cost at the factory gate in the US, is £643,600 at 2001 prices and exchange rates.

The institutional funder's long-term risk assessment concluded that, even if the fuel cell CHP did not ultimately perform as expected, the remainder of the project would still be viable. For example, if the stack replacement were not economic, then the PC25C could be shut down. The financial implications would therefore, be cost neutral, with TEL gaining the promotional benefits.

4.1.2 Economic Performance Compared with Photovoltaics

Rather than comparing fuel cell CHP with conventional CHP a more meaningful economic and environmental performance can be made with photovoltaics, another expensive green technology.

Woking currently has the largest concentration of photovoltaic installations in the UK amounting to $0.5MW_p$.

	Photovoltaics	Fuel Cell CHP
Elec. Generation	$200kW_p$	$200kW_e$
Heat Generation	-	$264kW_{th}$
Electricity Production pa	150,000kWh	1,629,360kWh
Heat Production pa	-	2,150,755kWh
Total Energy Production pa	150,000kWh	3,780,115kWh
Cost per kW	£6,000[1]	£5,325[2]
Cost per kW (Total Energy)	£6,000[1]	£2,255[2]
Reductions in CO_2 Emissions pa	150 Tonnes[3]	1,740 Tonnes[4]

1. UK DTI Major Photovoltaic Demonstration Programme 2002 – Guidance Notes: Section 4.
2. Woking Park Fuel Cell CHP Turnkey (supply and installation) Contract Price.
3.UK Energy Efficiency Good Practice Guide 116.
4. US Department of Energy (Fuel Cells 2000 Europe Conference 17-19 October 2002.

The current typical costs of photovoltaic installations in the UK is between £6,000 and £8,000 per kW_p. The cap for grant aid in the UK DTI Major Photovoltaic Demonstration Programme (website: www.est.co.uk) is £8,000 per kW_p and 5 years ago when the first large scale photovoltaic system was installed at Northumbria University in Newcastle the cost was £8,850 per kW_p. This demonstrates how far photovoltaic technology has come in terms of cost and utilisation which if the fuel cells industry could replicate by promoting fuel cell technology as a complimentary or alternative environmental technology to other green technologies such as photovoltaics, rather than as an alternative to conventional CHP, then the technology may enjoy early commercialisation as part of the family of low or zero carbon technologies.

4.2 Environmental Performance

The environmental performance of the fuel cell CHP is tested against the UK Combined Heat and Power Quality Assurance (CHPQA) programme, a mechanism for obtaining exemption from the UK Climate Change Levy payable on fossil fuels and centralised power generation. A brief explanation of the CHPQA Programme as an environmental performance indicator is given in this section and actual CHPQA Quality Index's (QI) are used not just for the fuel cell CHP but also in comparison with a number of the Council's conventional CHP systems. This comparison is for a real practical environmental tax credit system based on environmental performance.

4.2.1 Combined Heat and Power Quality Assurance Programme

As part of the UK Climate Change Programme the Government has implemented a new Combined Heat and Power Quality Assurance (CHPQA) programme and further information on the CHPQA standard, guidance notes and self-assessment forms is available on www.chpqa.com .

The CHPQA programme provides the method for assessing and certifying the quality of all types and sizes of CHP schemes. It is based on the energy efficiency and environmental performance of CHP schemes compared to electricity-only and heat-only energy supply.

'Good Quality' CHP is defined by the Quality Index (QI) approach. In general, for a CHP scheme to be certified as 'Good Quality' for its entire capacity and output, it will need, in operation, to achieve a QI of at least 100 (first year of operation only is allowed to have a QI of 95) and an electrical efficiency of at least 20%. Certified 'Good Quality' CHP determines the eligibility of CHP schemes for Climate Change Levy exemption, Enhanced Capital Allowances and exemption of plant and machinery from rating.

The QI is based on actual annual primary energy input and electricity and heat outputs as measured by certified metering.

4.2.2 Environmental Performance of the Fuel Cell CHP Compared with other CHP

The environmental performance of the Woking Park fuel cell CHP system is compared with a selected number of other Woking CHP systems based on the CHPQA programme. The following CHPQA indicators are all for the scheme performance year 2002 with the first 12 months performance of the Woking Park fuel cell CHP system including the first 3 months of intermittent/commissioning operation. A much higher QI should be achieved for 2003 based on the last 9 months of operation in 2002 and subsequent operation in 2003.

CHP Site	Capacity	QI	Power η	Heat η
Woking Park Fuel Cell CHP	200kW$_e$	110.77	32.12%	42.36%
Leisure Lagoon CHP	150kW$_e$	121.11	30.48%	48.12%
Civic Offices CHP	110kW$_e$	111.69	28.17%	44.28%
Woking Town Centre CHP – Ph. 1	1,350kW$_e$	101.37	25.96%	39.56%

4.2.3 Emissions

The primary emissions from the PC25C fuel cell in g/kWh of electrical power produced are as follows:-

CO_2	275
NO_x	0
SO_2	0

NO_x is negligible and SO_2 is 0.0004 g/kWh. With reference to Table 8 of the UK Energy Efficiency Best Practice Programme (EEBPp) Good Practice Guide 116 ‘Environmental Aspects of Large-Scale Combined Heat and Power’ both are effectively zero. CO_2 emissions is based on the US Department of Energy paper (Fuel Cells 2000 Europe Conference, London, 17-19 October 2000).

5. CONCLUSION

5.1 Technology Procurement

The aims and objectives of the project which was to design, install and operate a fuel cell CHP system in Woking Park, the first fuel cell CHP system in the United Kingdom was achieved. The benefits that were also expected to accrue from the project in an understanding of the full technology procurement process, the determination of the economic and environmental performance and an understanding of the commercial viability of a fuel cell CHP energy supply system in the new deregulated energy markets in the UK were also achieved.

The technology procurement process did tease out a number of issues in the planning, design, installation, operation and maintenance of the fuel cell CHP which are detailed in the report.

The planning process was a success only because of an understanding of the process by the Council officers involved in the project and the time and effort taken to submit detailed environmental information, to educate non technical people in an understanding of fuel cell technology and hydrogen and personal briefings given to planning officers and Councillors. This is an area very often not understood by the private sector so education of the fuel cell industry, or indeed any new technology industry, in this area will pay dividends in avoiding planning delays and the associated costs. Elsewhere in the UK with the CUTE project (a hydrogen fuel cell transport scheme) planning permission was refused for the hydrogen filling station for the London fuel cell buses at the first attempt through not paying enough attention in this area and the developer now has to appeal and/or resubmit information to counteract the ignorance over hydrogen and fuel cells.

Detailed work had to be put into the design process which was not unexpected for a project of this innovation and Council officers had previous experience with other innovative projects which helped to smooth the process. The technical information provided by the fuel cell CHP manufacturer: UTC Fuel Cells; was excellent and the specification and tendering would have been much more difficult without it. A detailed working knowledge has been gained in implementing this project which has stood the Council in good stead to implement further fuel cell and hydrogen projects.

The installation element of the project also teased out a few minor but potentially very important issues to be dealt with such as the uneven distribution of weight of the PC25C and the need for special lifting eyes for delivery. The main issue that had to be dealt with as part of the installation contract was the inclusion of the collection from the USA, shipping and importation into the UK, delivery and off-loading to site in Woking Park in the installation contract. This was necessary as UTC Fuel Cells would not deliver to the customer, either in the US or elsewhere in the world. This is an issue that needs to be addressed with future deliveries of fuel cells from the USA since it is not normal for the customer to arrange importation and delivery of major plant and in the future USA manufacturers will be in competition with UK, other European and world fuel cell suppliers. However, an unexpected benefit in the Council dealing with the importation into the UK of the fuel cell CHP was the import duty re-classification of the fuel cell CHP from a boiler to a heat exchanger decreasing the import duty from 2.7% to 1.7% and the agreement that the import duty would only be applied to the net cost of the fuel cell CHP (ie., less any grants). This has now set a precedent, at least for fuel cell CHP units imported into the UK.

The operation and maintenance elements of the project, and in particular the commissioning and the 3 months settling in process, provided valuable experience to all those concerned with the project in the UK. Of particular importance here was the inclusion of the training of the installation contractor's operatives in the USA to enable the installation contractor to properly operate and maintain the fuel cell CHP during the 12 months defects and omissions period overcoming any inter-contractual dispute issues and providing enough time for the Council and Thameswey to set in place their own resident engineers who were trained in the operation and maintenance of the fuel cell CHP during the 12 months defects and omissions period.

5.2 Economic and Environmental Performance

The economic performance of the fuel cell CHP was better than predicted, bearing in mind the high cost the PC25C. The original payback period estimated prior to implementing the project was 16.3 years but 11.8 years was actually achieved based on an exchange rate of $1.40: £1 sterling which was the exchange rate at the time of the procurement of the fuel cell CHP. If the exchange rate had been today's exchange rate of $1.65: £1 sterling the payback period of the project would have been 10.7 years and if the fuel cell stack replacement costs were reduced to $175,000 (Sure Power) instead of $300,000 (UTC Fuel Cells) the combined effect would have reduced the payback period to 10 years (10% IRR). This is a much better economic performance than photovoltaics which achieve paybacks on Woking's private wire networks of typically 20 to 25 years.

The environmental performance of the fuel cell CHP was excellent, as confirmed by the CHPQA programme. The fuel cell CHP out performed photovoltaics in terms of reductions in CO_2 emissions (more than 10 times the performance) even though the fuel cell CHP consumed a fossil fuel, albeit a low carbon fuel: natural gas. This is due to the fact that the fuel cell CHP is a continuous generator generating 10 times the electricity of an equivalent photovoltaic system plus generating heat as well. This is not to decry photovolatics as the Council sees this as an important renewable energy technology for an urban environment and its complimentary summer/winter reverse profiles with CHP has advantages in providing independent sustainable energy, particularly for residential communities, and its future potential as a renewable form of hydrogen via electrolysis. However, it is obvious that fuel cell CHP will make a much greater contribution towards the Council's Climate Change Strategy for Woking than the renewable energy technologies currently available to Woking.

5.3 Commercial Viability in the UK

From the economic comparisons with both the conventional UK fuel supply and conventional CHP it is apparent that the commercial viability of a fuel cell CHP energy supply in the new deregulated energy markets is not quite there yet from a financial perspective only, although it is quite close.

However, the driver in the UK and in Woking in particular, will not be just from a financial perspective. The UK has its Climate Change Programme and is committed to the Kyoto Protocol and is currently considering the Royal Commission on Environmental Pollution 60% reduction in CO_2 emissions by 2050 target as part of the Energy White Paper. In Woking, the Council adopted the Royal Commission on Environmental Pollution 80% reduction in CO_2 emissions by 2090 target in December 2002 and will need to implement significantly more zero and low carbon technologies such as CHP, renewable energy and fuel cells not just for buildings but for transport also, to achieve this target.

The Woking Park Fuel Cell CHP project has given Woking international publicity with significant interest from other local authorities and private developers in the UK to the point that fuel cells now feature in some of the Thameswey proposals for projects outside of Woking at the request of the customers.

In Woking the success of the Woking Park Fuel Cell CHP project has led to the Council incorporating fuel cell and hydrogen projects and investigations into its service plans as part of the Council's Climate Change Strategy for Woking. Of particular note here are the following projects:-

- Sustainable Waste to Energy Recycling Versatile Envirosystem (SWERVE). This project is already incorporated in the Council's service plan to achieve its recycling and renewable energy objectives and comprises a source/central waste separation system, materials reclamation facility, anaerobic digestion for the organic fraction of waste and gasification of the non organic, non recycable fraction of waste. The biogas and syngas outputs from the system will be supplied to modularised molten carbonate fuel cell technology to achieve a non combustion waste to energy system that will face much less public opposition and planning difficulties than conventional mass burn incineration. The project is the subject of a European Commission 6th Framework Programme application and is scheduled to be completed in 2006.

- Renewable Hydrogen Energy for the Built and Transport Environment (RHEBaTE). This project is based on large scale photovoltaics/hydrogen system for fuel cell transport and was to be the subject of a European Commission 6th Framework Programme application but one of the Council's partners: General Motors/Opel; pulled out at the last minute. The project is now being put together with different partners.

In addition, the Council has signed confidentiality agreements with a manufacturer of PEM fuel cell technology and is currently negotiating with another domestic PEM fuel cell CHP manufacturer for field trials of their technology in Woking.

From a Woking Borough Council perspective the Woking Park Fuel Cell CHP project has been a success and has stimulated a potential Renewable Energy/Hydrogen Economy approach not only to fulfil the Council's objectives under its Climate Change Strategy for

Woking but to address long term local security of supply issues. This in turn has stimulated significant interest in the UK to Woking's approach to sustainable energy.

6. REFERENCES

1. Woking Borough Council's Solicitation for Financial Assistance Application DE-PS26-99FT40516 under the US Department of Energy Climate Change Fuel Cell Program dated 25 March 1999.

2. Sponsorship Agreements with the UK Department of Trade and Industry and Advantica Technologies Ltd.

3. Report to Woking Borough Council's Policy and Resources Committee – 30 September 1999.

4. Report to Woking Borough Council's Development Control Sub-Committee – 3 August 1999.

5. Report to the Woking Borough Council's Planning Committee – 23 May 2001.

6. UTC Fuel Cells contract, contract amendments, specifications, installation and maintenance manuals.

7. Customer Delivery Report on the PC25C.

8. Woking Borough Council's installation contract and specification and the successful contractor's design submissions under the contract.

7. LIST OF ACRONYMS AND ABBREVIATIONS

BEMS -	Building Energy Management System
CHP -	Combined Heat and Power
CHPQA -	Combined Heat and Power Quality Assurance
CO_2 -	Carbon Dioxide
DETR -	Department of the Environment, Transport and the Regions (UK Government)
DNO -	Distribution Network Operator
DoE -	Department of Energy (United States Government)
DTI -	Department of Trade and Industry (UK Government)
DUoS -	Distribution Use of System
EEBPp -	Energy Efficiency Best Practice Programme
EESCO -	Energy and Environmental Services Company
ESCO -	Energy Services Company
NASA -	National Aeronautics and Space Administration (US Government)
NETA -	New Electricity Trading Arrangements
QI -	Quality Index (see CHPQA)
ROC's -	Renewable Obligation Certificates
TEL -	Thameswey Energy Ltd
TUoS -	Transmission Use of System
TW -	Thameswey Ltd
UPS -	Uninterruptible Power Supply
US -	United States

GRAPHS AND SCHEMATIC DIAGRAMS

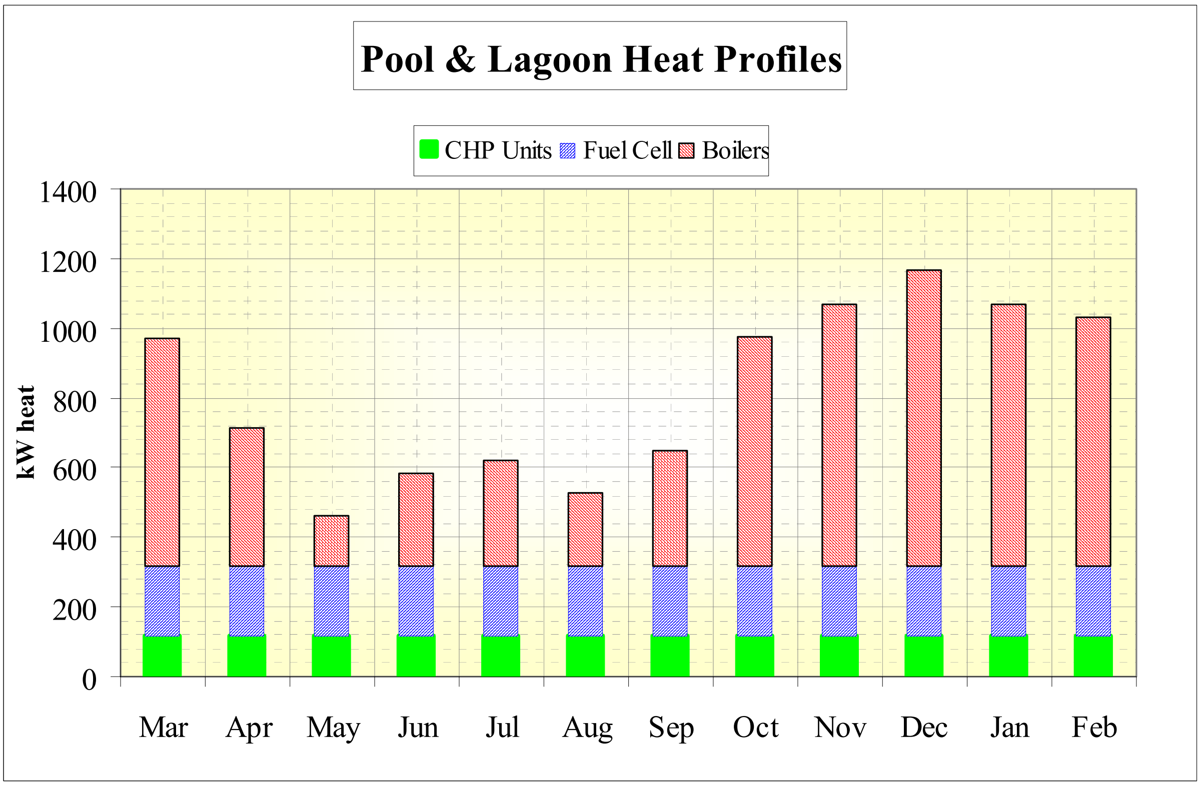


Figure 1

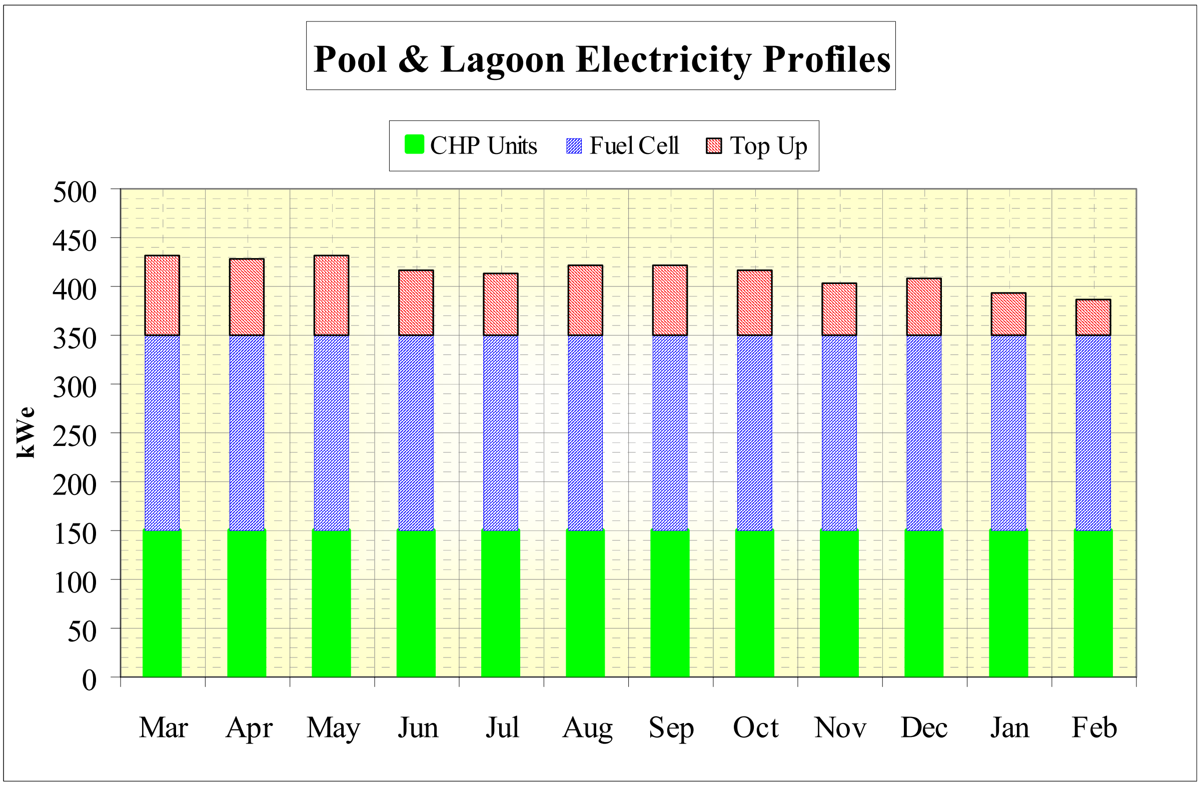


Figure 2

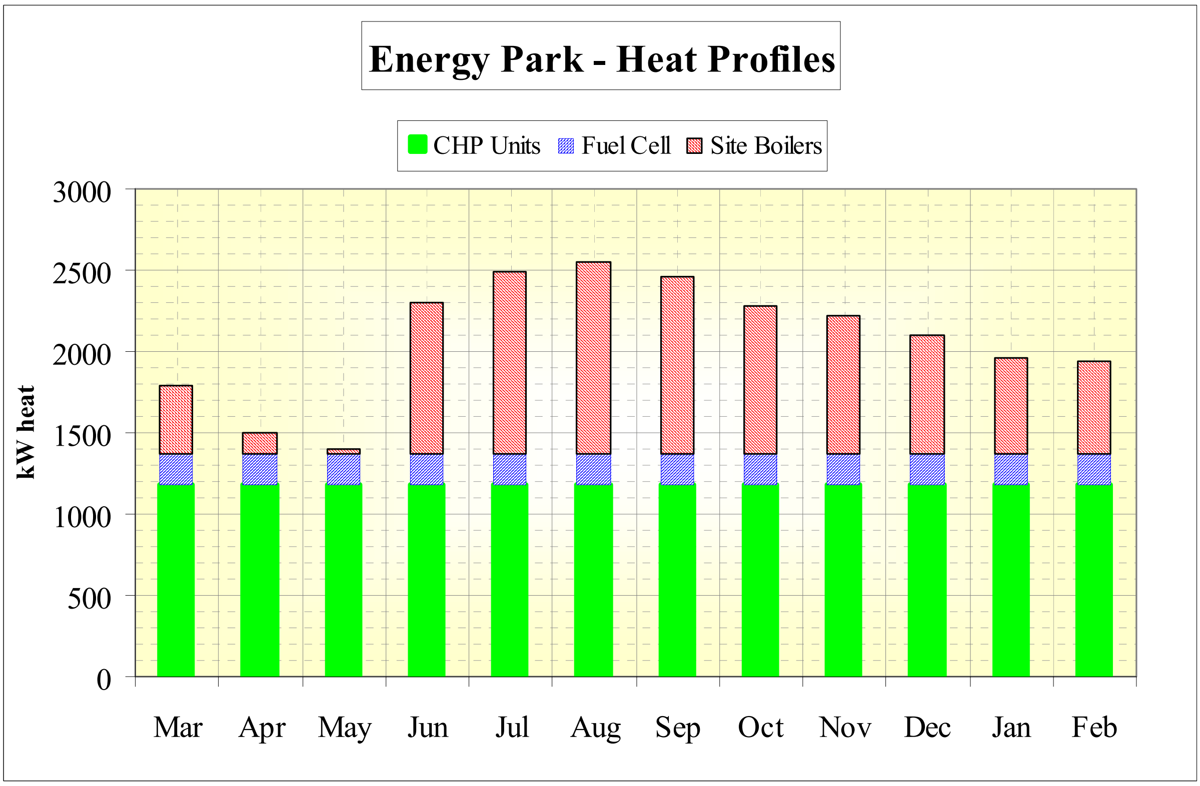


Figure 3

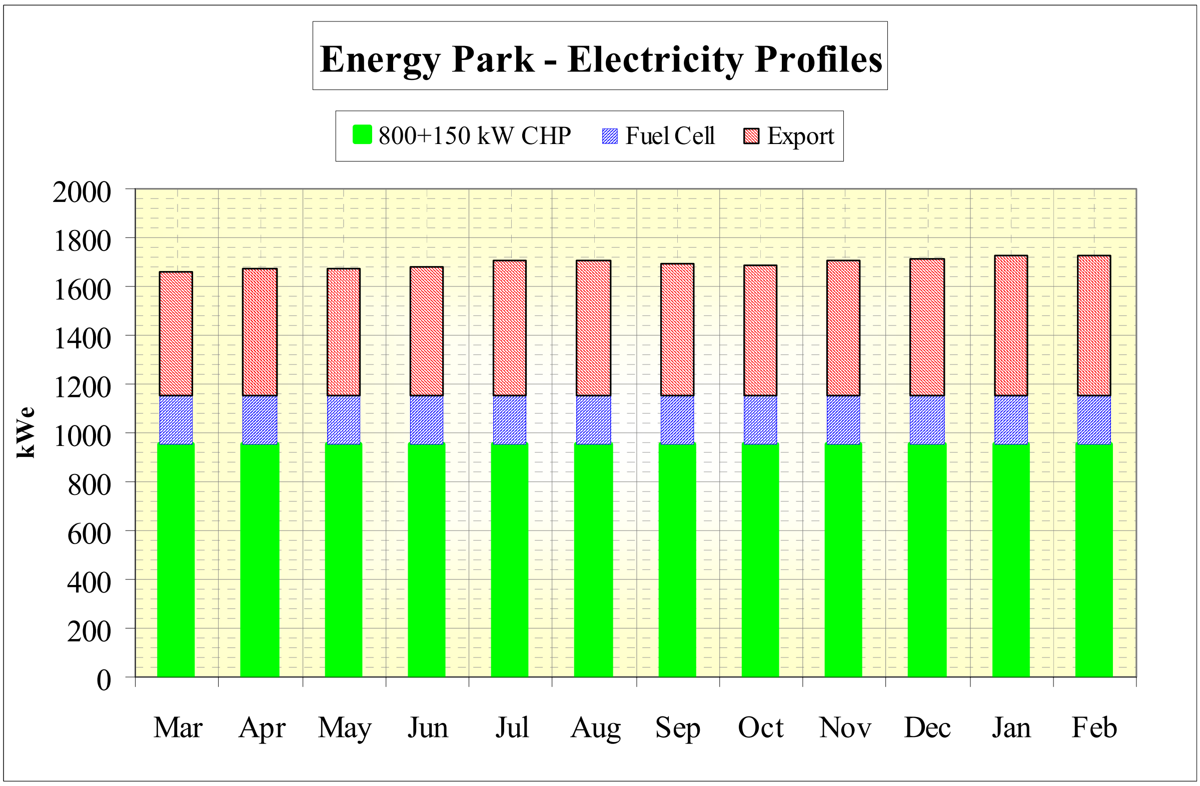


Figure 4

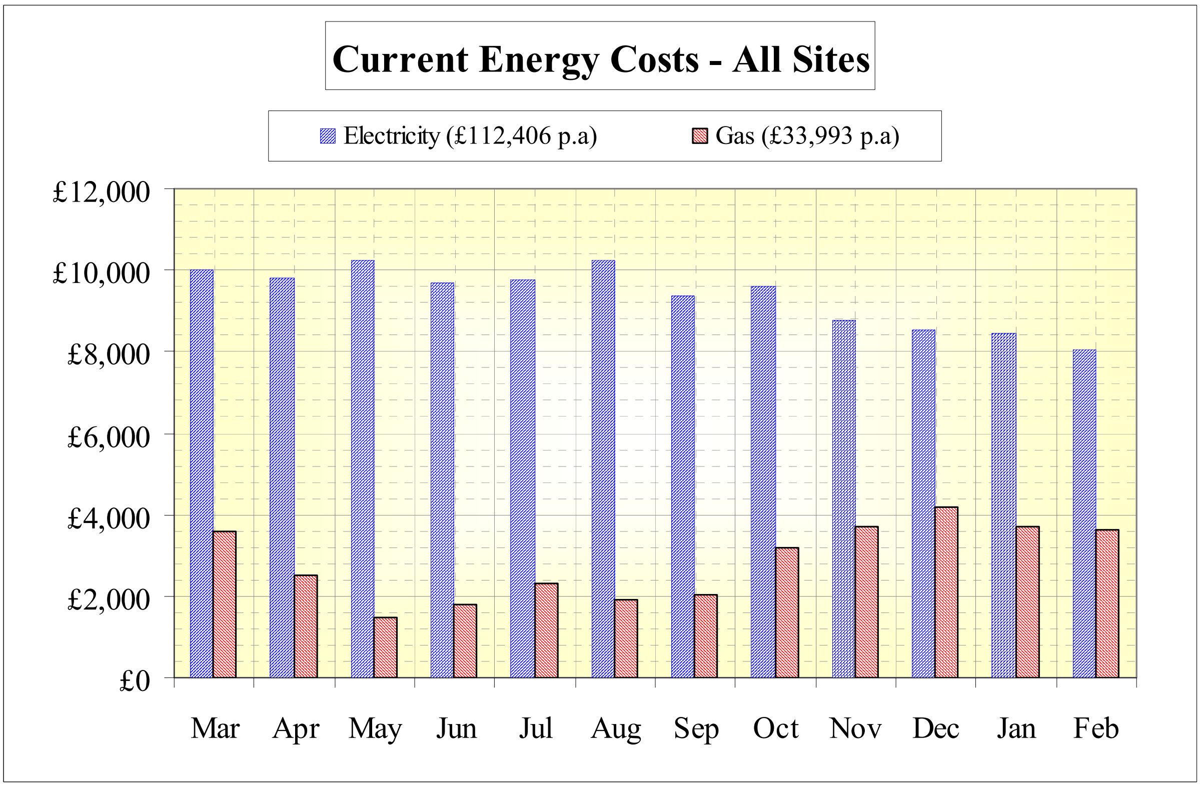


Figure 5

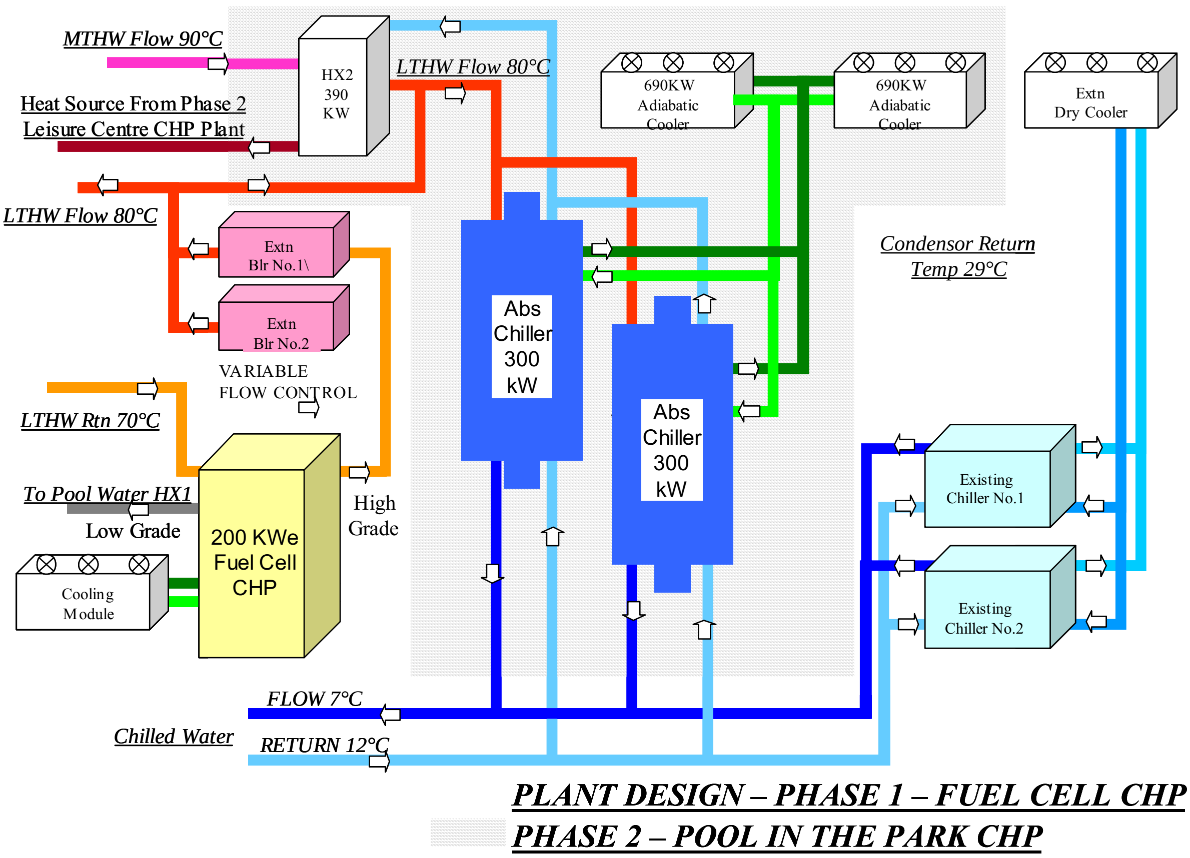


Figure 6

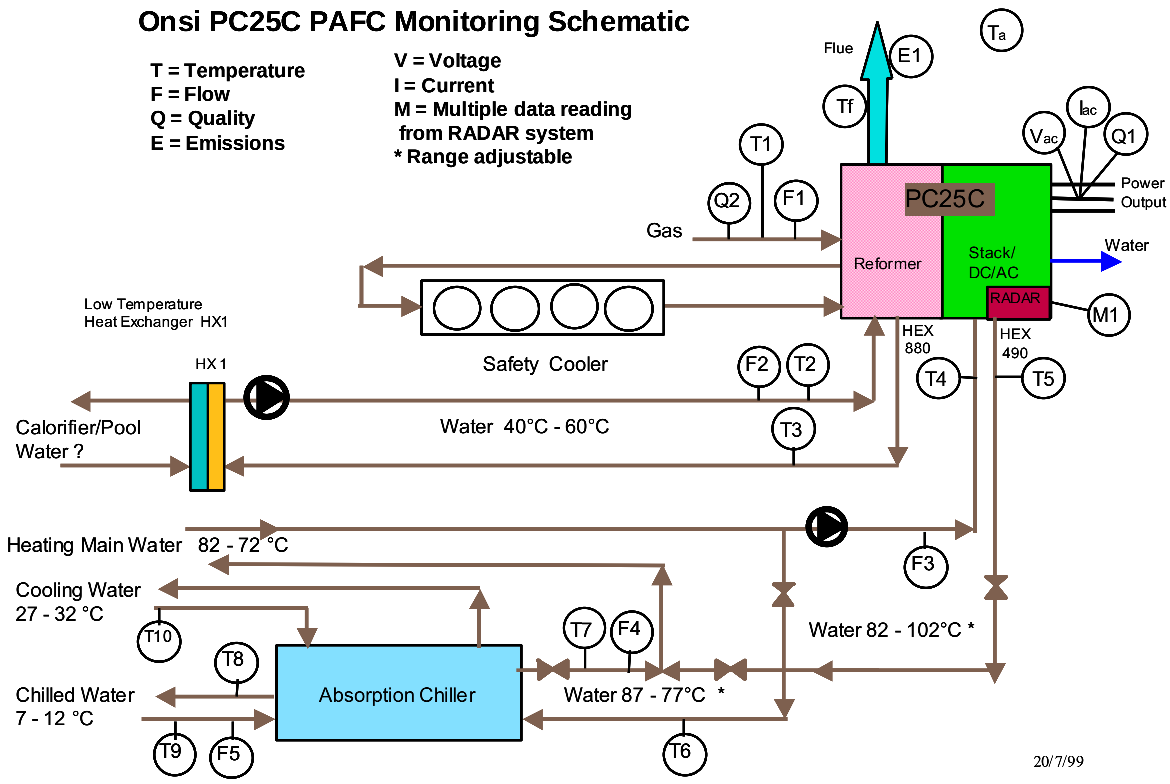
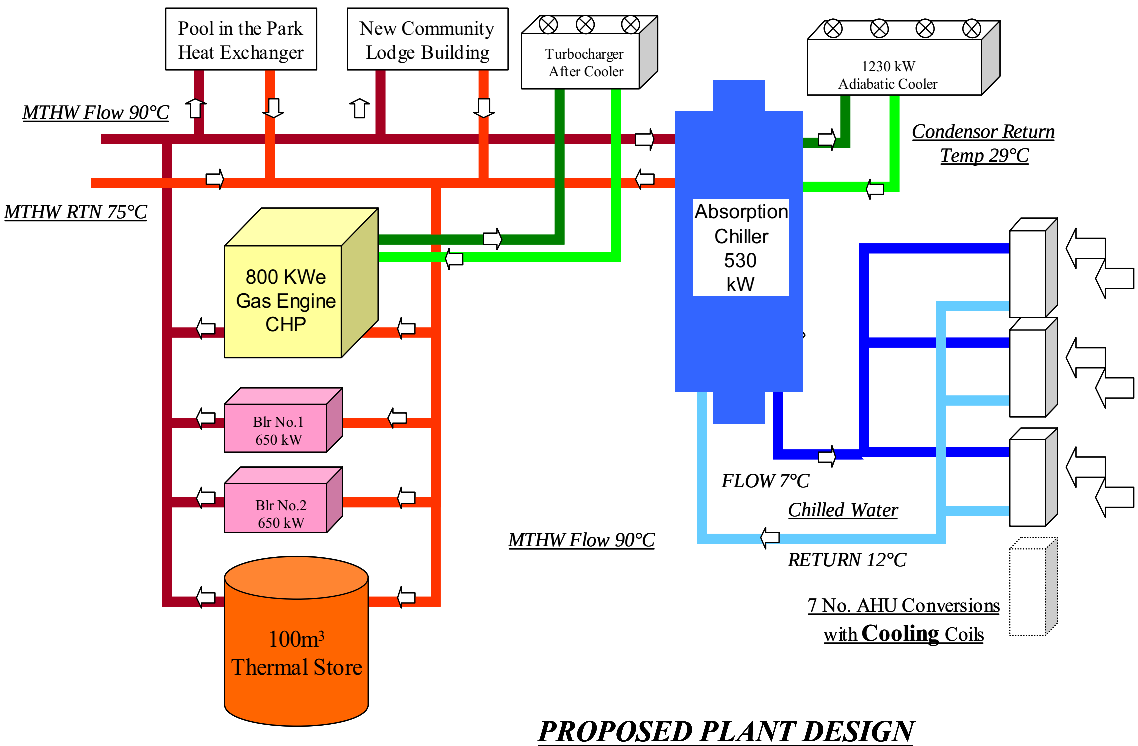


Figure 7



PROPOSED PLANT DESIGN
PHASE 2 – LEISURE CENTRE CHCP

Figure 8

APPENDICES

APPENDIX 1

Report to the Policy & Resources Committee, Agenda Item 4, 30 September 1999

The following paper formed the basis for Woking Borough Council to approve the formation of a wholly owned energy and environmental services company (Thameswey Ltd) and of a public/private joint venture energy services company (Thameswey Energy Ltd), in which Thameswey Ltd., represents the Council's interest.

Agenda Item No. 4

POLICY AND RESOURCES COMMITTEE - 30 SEPTEMBER 1999

ENERGY AND ENVIRONMENTAL SERVICES COMPANY (EESCO) - THAMESWEY

1. Purpose

1.1. This report seeks approval for: -

- the establishment of a wholly Council owned energy and environmental services company, Thameswey Limited (TW);
- the use of the Council's registered trademark by Thameswey for trademark license schemes;
- the establishment of a joint venture company, Thameswey Energy Limited
- (TEL);
- the initial project plans of TEL;
- authority to be delegated to the Chief Executive to complete the documents
- forming TW and TEL;
- authority to be delegated to the Chief Executive in consultation with the
- Chairman of Committee to authorise TW to progress the projects in
- accordance with the arrangements set out herein.

2. Introduction

2.1. The Committee at its meeting on 26 November 1998 resolved that: -

- TW be established subject to favorable advice from Leading Counsel;
- the TW logo be registered as a trademark;
- the Chief Executive and the Director of Central Services be authorized to approve the detailed arrangements for the establishment of TW in consultation with Group Leaders;
- the Director of Central Services be authorised to investigate further joint ventures and report thereon.

2.2. The EESCO concept was outlined in a paper produced by Allan Jones (Energy Services Manager) which was attached as an appendix to report DCen 1085 which was considered by the Committee at its meeting on 2 July 1998. As background the paper is reproduced as Appendix 1 to this report.

2.3. Investigations and negotiations to enable the Council to implement its Business Plan objective of forming an EESCO are now substantially complete. Authority has been delegated to proceed with the establishment of TW. However, it is considered that, as the proposals will affect the way in which the Council procures energy related services in the future, the Committee should be given the opportunity to consider the concept further. If the recommendations herein are supported the Committee is requested to resolve to proceed subject to the provisions set out within this report.

2.4. It is important that the Committee recognises that pursuing its environmental and energy efficiency objectives in partnership with the private sector will expose it to the risk that if the proposed ventures fail to succeed the Council may lose some or all of its investment. In progressing this initiative officers have sought to minimize the risk to the Council. Whilst the Committee can be assured that the matters before it are properly within the Council's legal powers and wholly consistent with the Government's environmental initiatives commercial success cannot be guaranteed.

3. London Electricity

3.1. The Council had been engaged in discussions with London Electricity (LE) on the formation of a joint venture EESCO. Entergy, (LE's parent) put LE up for sale towards the end of 1998. As part of the sale arrangements Entergy placed a moratorium on new investment. As a consequence of the financing decision LE introduced a new party into the discussions, Difko A/S (Difko), as the prospective financing partner of the joint venture. Earlier this year Entergy sold LE to Electricite de France (EDF). By the time of the sale it had been established that the interests of the Council and LE were not sufficiently aligned to enable the proposed joint venture to meet each party's objectives; negotiations were therefore amicably terminated.

3.2. Difko, who had joined the discussions confirmed its interest in progressing the initiative and expressed positive interest in becoming the joint venture partner. Accordingly negotiations continued with Difko.

4. Difko

4.1. The Difko Group was established by the Danish Investment Foundation, an international finance house originally founded in 1976 to channel capital from individuals into business life (shipping, property, farming, commerce and industry).During the eighties and early nineties more than 75 investments have been made in limited partnerships by over 60,000 private individuals in Denmark with a total investment of more than 1 7 billion DKK (£1.5 billion).

4.2. Today, the Foundation specialises in capital co-ordination and project development, mainly in the spheres of shipping and green energy production. The Foundation sees its task as that of an independent problem-solver in the interplay between the investor and the lender, as well as investing its own funds in shipping and green energy projects through Difko A/S, now the largest private investment house in Denmark. This approach in the green energy field is one of the reasons why Denmark is a world leader in green energy with such technologies as CHP, biomass and other renewables at home and abroad (Difko owns over 2,000 wind energy systems in California alone).

4.3. In 1997 Difko established ESCO International S.A. (Energy Saving Company) with offices Warsaw, Poland and Aarhus, Denmark, specialising in the building, financing and operation of decentralised CHP plants in Eastern Europe and elsewhere in the world.

4.4. Established in 1985 LR Energi A/S offers turnkey solutions for a broad range of industrial and residential applications, and has an impressive track record in implementing energy efficiency projects in Scandinavia and Central and Eastern Europe. Difko acquired a shareholding in LR Energi of 50 in 1997, bringing together a full design and contracting turnkey capability for green energy projects

4.5. The bringing together of Difko (and its sister green energy companies) and the Council into a joint venture company will combine the finance and considerable experience and expertise in CHP and renewable energy of a leading company in this field with the innovative and unique experience and expertise in the combination of green technologies with private wire and absorption cooling in a fully deregulated energy market which will give important pointers to the future energy deregulation in Europe, USA and elsewhere in the world.

5. Thameswey Limited (TW)

5.1. TW is proposed as a wholly owned Council EESCO whose principal objects are:

- to promote energy efficiency, energy conservation and environmental objectives by providing energy and/or environmental services;
- to develop and implement technologies for the production and supply of energy;
- to produce and supply energy (and any related by products) in all its forms;
- to acquire and hold interests in the share capital or loan capital of any company or corporation and in particular in companies engaged in energy and/or the environmental business;
- to provide financial, managerial and administrative advice, services and assistance;
- to make facilities and services available for its customers and customers of companies in which it holds an interest.

5.2. These objects are deliberately drawn widely but are restricted to those matters upon which Leading Counsel has been able to advise fall strictly within the legal powers of the Council. TW will be subject to the same provisions of control upon capital expenditure and vires as the Council.

5.3. It is proposed that the company have an authorised share capital of £1m divided into shares of £1 each. The Council will hold all shares. No individual shall be entitled to hold shares. The initial purchase of shares in TW shall be £250,000 to be financed from the Energy Efficiency Reserve.

5.4. The Board of Directors shall comprise of a minimum of three and a maximum of five executive directors together with a minimum of one and a maximum of three non-executive directors. Initial appointments will be made as follows:-

Executive	Chief Executive of the Council
	Two Directors from the Council's Management
	Borough Secretary and Solicitor of the Council
	Energy Services Manager of the Council
Non Executive	Richard Tinson (Director, National Energy Foundation)

5.5. Executive Directors shall not be entitled to any remuneration. Non Executive Directors shall be entitled to remuneration up to a maximum sum, which shall be determined by the Council from time to time.

5.6. The Directors shall manage TW in accordance with an annual business plan and budget approved by the Council. TW will submit its Business Plan and Budget for approval by the Council at the same time as the Council considers its own Business Plan and Budget. TW will indemnify the Directors against any liability incurred in defending proceedings and against premia payable in respect of insurance for acting as directors and officers of the company.

5.7. TW will not declare dividends. All profits of TW available for distribution will be retained for reinvestment.

5.8. The Council will enter into a contract with TW to appoint it as its contractor to implement the Council's policy of investing in Combined Heat and Power (CHP) plant to generate and sell heat and power in an environmentally efficient way with a view to improving the environment within it's area.

5.9. TW will. in time, seek similar contracts from other Local Authorities to procure additional investment opportunities for its joint venture TEL.

5.10. TW's initial work programme will comprise of:

- participation in the proposed joint venture company Thameswey Energy Limited (TEL);
- adoption, branding and expansion of the existing energy conservation schemes
  i) Local Energy Efficiency Home Discount Schemes (LEEHDS),
  ii) Free Energy Efficiency Advice Scheme,
  iii) Condensing Boiler Home Energy Rating Scheme,
  iv) Home Energy Saving SRB Scheme,
  v) Home Energy Saving CRI Scheme.

- pursuit of initiatives to assist the Council in achieving its Home Energy Conservation Act (HECA) objectives;
- investigation, at the invitation of other public bodies, into similar contractual arrangements as outlined in paragraph 5.8 and 5.9 above;
- investigation into a scheme to address the needs of the "fuel poor";
- investigation into further joint ventures where appropriate.

5.11. TW will procure support services from the Council. In the first full year (2000/01) these will be in the notional sum of £10,000. In future years, after experience has been gained of the extent of work required this would be reconsidered during the review of the Business Plan and Budget. Professional services required to further specific projects will be charged to and financed by the project.

6. Trade Mark

6.1. The Council holds a registered trademark "Logo" for Thameswey. It is proposed that both the Council's wholly owned company and joint venture companies established by Thameswey be licensed to use the Logo.

6.2. Some of initiatives envisaged by the Government for an EESCO have been established to be beyond the legal powers of the Council to undertake. In discussions with Leading Counsel he has advised that the Council could promote the activities by the private sector or other bodies through the use of its Trade Mark. In such circumstances he was able to advise that the Council would be obliged to charge for the use of the Logo as its intellectual property. Accordingly its is proposed that those matters which the Council cannot directly undertake but further the objectives of promoting energy efficiency and/or environmental improvement will be pursued by TW upon behalf of the Council.

6.3. Initially the existing schemes identified as to be adopted by TW will be branded with the Thameswey Logo. New schemes will be initiated by TW in furtherance of its HECA and Local Agenda 21 work on behalf of the Council and be similarly branded with the Thameswey Logo.

7. Thameswey Energy Limited (TEL)

7.1. TEL is proposed as a joint venture EESCO whose principal objects are:

- to own and operate plant for the production and supply of electricity, heat and chilled water to customers and activities ancillary thereto;
- to develop and implement technologies for the production and supply of energy;
- to produce and supply energy (and any related by-products) in all its forms.

7.2. These principal objects are restricted to those matters upon which Leading Counsel has been able to advise fall strictly within the legal powers of the Council. TEL will not be subject to the same provisions of control upon capital expenditure as the Council.

7.3. It is proposed that the company have an authorised share capital of £4,995,000 divided into 4,000.000 "A" shares of £1 each and 995,000 "B" shares of £1 each. Difko Energi A/S (Difko) will hold A shares and Thameswey (TW) (the Council's wholly owned company) will hold B shares. The initial purchase of shares in TW shall be £81,000 "A" shares purchased by Difko and £19,000 "B" shares purchased by TW.

7.4. The TEL Board shall be six Directors. The Chairman will be non-executive, Difko will appoint four executive directors, TW will appoint one executive director. Following discussions with Difko it is proposed to appoint Richard Tinson (Director, National Energy Foundation) as the non executive Chairman.

7.5. Executive Directors shall not be entitled to any remuneration. Non Executive Directors shall be entitled to remuneration up to a maximum sum, which shall be determined by TEL from time to time.

7.6. The Directors shall manage TEL in accordance with an annual business plan and budget approved by the shareholders. TEL will submit its Business Plan and Budget for approval by shareholders. TW will incorporate TEL proposals in its Business Plan and Budget which it will submit to the Council at the same time as the Council considers its own Business Plan and Budget. TEL will indemnify the Directors against any liability incurred in defending proceedings and against premia payable in respect of insurance for acting as directors and officers of the company.

7.7. TEL will declare dividends. All profits of TEL available for distribution during the first five years of operation will be retained for reinvestment.

7.8. TEL's initial work programme will comprise of:

- Woking Town Centre Combined Heat and Power (CHP) in phases -
  Phase 1 Civic Offices, Planets, Victoria Way car park, Holiday Inn Hotel and the Church Street East restaurant building;
  Phase 2 Safeway Store, Goldsworth Road;

- Woking Park CHP in phases -
  Phase 1 Fuel Cell,
  Phase 2 Pools and Leisure Centre;

- Woking Borough Council existing energy plant;
- schemes to provide CHP to Council owned housing stock;
- investigation, at the invitation of other Local Authorities and/or private businesses, into similar schemes as outlined above.

7.9. TEL will procure support services from TW. In the first full year (2000/01) these will be in the notional sum of £10,000. In future years, after experience has been gained of the extent of work required this would be reconsidered during the review of the Business Plan and Budget. Professional services required to further specific projects will be charged to and financed by the project.

8. Proposed next steps

8.1. |To implement the proposals the Council will need to proceed to form both TW and TEL. The necessary documentation to effect the transactions are predominantly complete. It is therefore proposed that, subject to the Committee's agreement the Chief Executive be authorised to execute the documents.

8.2. Following the formation of the companies it will be necessary for TW to approve the projects proposed by TEL. The Board of Directors of TW require authority to enter into these arrangements. When the company is established and operational it will seek annually authority from the Council for its work programme; this is not yet possible . Accordingly it is proposed that the Chief Executive be authorised, in consultation with the Chairman of the Committee, to authorise TW to enter into the projects outlined below and upon the basis set out herein.

Woking Town Centre Combined Heat and Power Phase 1

The project comprises the Civic Offices, Planets, Victoria Way car park.Holiday Inn Hotel and the Church Street East restaurant building. The current work programme envisages the entering into obligations in respect of this project by 20 October 1999 based on Stannifer Hotels Limited's proposals to proceed with the Holiday Inn Hotel development in early November 1999. Initially the Council and Difko will enter into Heads of Terms for the procurement of the scheme by TEL - the Council's and Difko's liabilities will be joint and several and be time limited to the bringing forward of the project to the end of the defects period. All future liability will be limited to TEL and the Council's risk limited to its shareholding in TEL via TW. The project cost is estimated at £2.5m. The share capital investment by TW in this project will be £100,000. The Chief Executive will be requested to proceed with this project under delegated authority by 20 October 1999.

Woking Town Centre Combined Heat and Power Phase 2

This project comprises the Safeway Store, Goldsworth Road with potential for connection to other local premises. The current work programme envisages the entering into obligations in respect of this project by the end of 1999 based on Safeway's current proposals. The project cost is estimated at £1.5m. The share capital investment by TW in this project will be £60.000 . The Chief Executive will be requested to proceed with this project under delegated authority in consultation with the Chairman of Committee. Woking Park CHP This project comprises the Fuel Cell with the potential to extend the scheme to incorporate existing leisure buildings. The project has been tendered and is currently being evaluated. It is unlikely that the original time-scale for the Fuel Cell element can be achieved. To progress the scheme it will be necessary to report to a future meeting of the Arts Leisure and Tourism Committee on the benefits to the existing leisure buildings. The full project cost is estimated at £3.3m. The share capital investment by TW in this project will be £1 30,000. The Chief Executive will only be requested to proceed with this project under delegated authority in consultation with the Chairman of Committee following favourable consideration by the Arts leisure and Tourism Committee.

Woking Borough Council existing energy plant.

This includes plant in both General Fund and Housing property. To progress this project a report will be submitted to the next meeting of Housing and Community Services Committee. It is currently estimated the capital receipt available to the Council would be in the order of £1m and that revenue savings would accrue. The full project cost is estimated at £1.1m. The share capital investment by TW in this project will be £44,000. The Chief Executive will only be requested to proceed with this project under delegated authority in consultation with the Chairman of Committee following favourable consideration by the Housing and Community Services Committee. TW will require a further injection of share capital by the Council to proceed with the Woking Park and or the existing Council plant proposals. It is proposed that £250,000 of additional share capital be invested from the capital receipt obtained by the transfer of the existing Council plant into TEL. If the Committee supports this proposal it will be incorporated in the appraisal to be submitted to the Housing and Community Services Committee in respect of existing Council plant.

9. Implications

Legal Advice - Comments of the Borough Secretary and Solicitor

9.1. This project has throughout its development required careful legal evaluation. There are several reasons for this. First, and most fundamentally, a local authority may only do that which it has statutory power to do. The innovative nature of the project means that the Council must place reliance on powers that owe more to the historic pattern of electricity generation than the demands of the present day. Secondly, in devising arrangements, it has been important to ensure that the Council is not seeking, by device or other vehicle, to extend its powers. Finally, we have had to consider, and where necessary distinguish, those cases which have cast doubt on the abilities of local authorities to participate in companies.

9.2. Mr Mark Lowe QC, a specialist in local government and administrative law, has provided much valuable advice in conference and in writing. He has approved the structure of the scheme and the detailed documentation it entails. Mr Lowe has advised throughout the evolution of the project and his Opinion of May 1999 (to which an addendum of July 1999 is attached) is available to members as a confidential document.

9.3. The core power upon which the Council relies in entering into these arrangements is contained in section 11 Local Government (Miscellaneous Provisions) Act 1976. This provision enables the Council to: -

- produce heat or electricity or both;
- establish and operate...generating stations and other installations;
- buy or otherwise acquire heat;
- use, sell or otherwise dispose of heat produced or electricity produced by the authority;
- enter into agreements for the supply by the authority to premises within or outside the authority's area of heat and steam produced from and air and water heated by such heat.
-

9.4. So far as the Council's proposals are concerned, the provision is not perfect (statutory powers seldom are). Since section 11 plainly does not provide a complete code as to the Council's powers in respect of this activity, the Council may therefore rely upon its implied power under section 111 Local Government Act 1972. Section 111 provides that the Council shall have the power to do anything "which is calculated to facilitate, or is conducive or incidental to, the discharge of any of (its) functions".

9.5. Recent cases have revealed the limits of section 111. This incidental power cannot be used in contexts where Parliament has provided a complete code for the exercise of local authority functions; moreover its use must be consistent with, and in furtherance of, the objects of the principal power. It has therefore been important to ensure that, if the Council is to use the vehicle of a company, that company must act demonstrably as the Council's contractor or agent in the production and sale of electricity. The proposed structure accordingly provides that TW acts as the contractor or agent of the Council in respect to these matters. The Council will decide what joint venture arrangements, if any, are appropriate for TW's participation. TW can then enter into the joint ventures, as the Council's agent, to bring about the Council's wishes. Since TW is wholly owned and controlled by the Council, there should be no problem in the Council using it as its agent and delegate. The creation of the company and any express agency arrangement between it and the Council will be authorised under section 111 as being something incidental to the exercise of the Council's functions under section 11 of the 1976 Act.

9.6. The risk in these arrangements, and it is one which must be taken into account, is that in some future case a court will decide that local authorities have no power to incorporate limited companies under section 111. Leading Counsel expresses the view, and I agree, that such a decision would fly in the face both of current practicein the field of partnership initiatives and of the assumptions that lie behind the provisions regulating local authority companies. Moreover the structure of the proposal coincides with the encouragement given by government to joint venture in the delivery of services between the public and private sectors.

9.7. Leading Counsel explores these issues in detail in his Opinion. He states his conclusions as follows:

- The Council has the power to form and invest in TW. The power arises from the use of TW as the agent or contractor to the Council, both incorporated and employed under the incidental power arising under section 111 of the 1972 Act to supplement that provided by section 11 of the 1976 Act;
- TW's role as a contractor acting for the Council and subject to its authorisation ensures that the use of the company complies with the views of the Court of Appeal in the Credit Suisse cases as to the use of local authority companies;
- TW, as a company wholly controlled by the Council, would have the ower to invest in TEL and other Joint Venture Companies restricted to providing the services required by the Council in exercise of its powers under section 11 of the 1976 Act. The power arises both under section 111 and, perhaps, under the provisions of Part V of the Local Government and Housing Act 1989 and Article 11 of the Local Authorities
- (Companies) Order 1995;
- The proposed Memorandum and Articles of TW appear to comply with the requirements of the 1995 Order;
- The proposed arrangements set out in the draft Memorandum and Articles of TEL, in conjunction with the provisions of the proposed Shareholders Agreement are sufficient to ensure that TEL will not become a regulated company under the terms of the 1995 Order;
- The Council has the power to licence the use of the TW registered trademark and the proposals are satisfactory for the purpose.

9.8. I agree with these conclusions and I share the view of Leading Counsel that it is within the powers of the Council to participate in these proposals in the form contemplated.
Financial

9.9. Under the proposals the Council will be required, from time to time, to invest in the share capital of TW. TW will then invest in the TEL joint venture, or such other joint ventures as may from time to time be approved by the Council as the shareholder of TW.

9.10. Initially the Council will invest £250,000 in the share capital of TW financed from its reserve for energy efficiency projects. If the proposed Woking Park and existing Council plant projects are to be progressed a further investment of £250,000 in share capital will be required to be financed from the capital receipt from the transfer of existing Council plant.

9.11. TW will accrue income from the use of the Trade Mark licence. It is not possible at this stage to assess the level of income to be achieved from this source.

9.12. TW will also receive an arrangement fee of up to 2.5 of the bank finance element of each project undertaken by TEL. Based on the current project programme this should generate in the order of £100,000 during the first twelve months of operation. This income will be available for further investment in share capital of TEL.

9.13. For new projects which the Council as landowner requires TEL to undertake it will be required to invest additional share capital in TW equivalent to at worst 10 and probably nearer 4 of the capital value of the project. By way of example, if the Council requires replacement plant and equipment which would normally be £200.000 TEL may invest in a CHP project costing some £500,000 which not only replaces the plant but provides CHP services to the Council and others. To progress the initiative the Council would need to invest circa £20,000 at best and at worst £50,000. This approach offers significant capital savings and provides a more environmentally friendly and energy efficient solution.

9.14. In time TW will be able to recycle money to acquire more shares in TEL, i.e. it will become self financing. It is not possible to forecast accurately when this will arise, however, from year six onwards it will receive income from TEL which should assure it has sufficient income to continue to invest in new projects without continuing to look to the Council for more capital. In any event the Council has no obligation to invest in additional share capital in TW.

9.15. When TW pursues projects with third parties, particularly those outside of the Borough, it will seek an arrangement fee in the order of 10 of the capital project which it seeks to progress through TEL. Clearly the level of fee will be dependent on what the project will bear, the important point is that Woking taxpayers will not be required to put additional share capital into TW in order to progress projects outside of the Borough.

9.16. The Council will initially provide administrative and management services to the wholly owned company (TW) which in turn will service the joint venture company (TEL). The Council will initially charge a nominal sum of £10,000 for its services, although any projects specific costs will be charged in addition to the base fee and be included in the capital cost of a project. This arrangement will be kept under review and the price adjusted accordingly. Because TW and TEL are pursuing the Council's existing objectives it is possible to manage the initial activity within existing resources. Should the TEL venture prove extremely successful it could expand to a point beyond which the

Council could reasonably expect to service it through its wholly owned company, TW. When such a point is reached TEL and TW will need to reconsider staffing arrangements and the Council as shareholder of TW will need to approve the proposals in the annual review of the TW Business Plan.

9.17. The key financial issue is that the Council will, in investing in TW, place its money into share capital of a limited liability company. If the company should fail, or the joint venture TEL should fail, the Council will risk losing its capital. The schemes currently proposed do not present any significant risk, i.e. the "customers" are either the Council (Civic Offices, Planets, Victoria Way car park, Woking Park, existing Council Plant) or medium risk commercial companies (Stannifer "Holiday Inn" Hotel, Safeway stores).

9.18. The potential for capital savings is significant. The Council should, through the TW and TEL companies, be able to progress its energy and environmental objectives at a fraction of the cost it would otherwise incur in replacement existing black energy plant.

Environmental and Planning

9.19. Each project involving new construction will require planning consent. In supporting the proposals the Council is not bound to approve any building other than on its merit. Nothing in this report expresses or implies that any planning consent will be granted.

9.20. The environmental benefits are substantial. Each project will introduce sustainable energy and displace black energy with resultant reductions in emissions and increase in efficiency.

Human Resources

9.21. The are no additional human resource issues raised by this report at this time. Should the TW or TEL companies become extremely successful it may require the employment of additional personnel by the said companies. There are no proposals to increase Council staffing arising from this report.

10. Conclusions

10.1. The Committee has before it the opportunity to progress its objective of establishing an Energy and Environmental Services Company (TW) and to enter into a joint venture with Difko to form an energy production company (TEL). There are significant environmental benefits to be accrued from progressing this initiative. The cost of establishing the companies, £250,000 of share capital in TW may be financed from the Council's Energy Efficiency Reserve. The joint venture with Difko (TEL) will enable the construction and operation of CHP plant which will displace the need for the Council to invest in replacement of existing black energy plant. Use of TEL to provide energy plant will offer the Council substantial capital savings. If the Council proceeds with the transfer of its existing plant to TEL it will reinvest £250,000 of the capital receipt in TW to facilitate the financing of further projects.

10.2. The Council has the necessary legal power to progress the initiative as proposed.

10.3. The Committee must take into account that commercial success cannot be guaranteed and that the Council's share capital investment will be at risk.

11. Recommendations

11.1. The Committee is requested to:

RESOLVE that

1. the establishment of a wholly Council owned energy and environmental services company, Thameswey Limited (TW) be approved;

2. the use of the Council's registered trademark by Thameswey for trademark licence schemes be approved;

3. the establishment of a joint venture company, Thameswey Energy Limited (TEL) be approved;

4. the initial project plans of TEL be approved;

5. authority to be delegated to the Chief Executive to complete the documents forming TW and TEL;

6. authority to be delegated to the Chief Executive in consultation with the Chairman of Committee to authorise TW to progress the projects in accordance with the arrangements set out herein.

This Committee has authority to determine the above recommendations.

APPENDIX 2
Report to the Planning Committee - 23 May 2001

The following is the final report to the Council's Planning Committee, which granted planning permission to the installation of the fuel cell CHP. This second planning application was required following a change of location of the fuel cell CHP.

4 01/0314 Datereg: 20.03.01 Date Con: 12/04/01 Ward: H

LOCATION:	**Pool in the Park, Kingfield Road, Woking GU22 9AA**
PROPOSAL:	**Erection of an extension to the Pool in the Park to accommodate fuel cell plant, thermal store and 27 metre high flue. Installation of plant on the roof of the Leisure Centre and erection of additional footbridge across the stream carrying fuel cell services.**
TYPE:	**Full**
APPLICANT:	**Thameswey Energy Ltd**
OFFICER	**DT**

SUMMARY OF PROPOSED DEVELOPMENT

This is a flagship "green" energy scheme to power and heat the Council's buildings within the park. Additions to the Pool in the Park to facilitate the installation of a fuel cell plant, thermal store and 27 metre high flue; also the installation of plant on the roof of the Leisure Centre, and the construction of a bridge across the Hoe Stream intended to carry the services to the fuel cell. (N.B all existing footbridges and pathways are to be retained).

PLANNING STATUS

- Urban area
- Urban Open Space
- Flood Plain
- River Corridor

RECOMMENDATION

Approve, subject to conditions

SITE DESCRIPTION

The Pool in the Park and Leisure Centre are situated on a site of 17.4 hectares, with the Hoe Stream running east/west through the centre of it The Leisure Centre and Pool are located roughly in the centre of the Park, the former to the south of the Hoe Stream the latter to the north. To the north of the Pool is an extensive area of playing fields and tennis courts. Service accesses run immediately along the north of the Pool to an entrance adjacent to the external flumes. This is also one of the main thoroughfares through the Park. There is also a service road to the Leisure Centre, accessed from Elmbridge Lane. The whole Park is very well treed, with the thoroughfare through the park being lined with an avenue of horse chestnut trees, weeping willows along the bank to the Hoe Stream and various specimen trees situated throughout the park.

Woking Park is surrounded by residential areas, the closest being Queen Elizabeth Way Woodlands, Park View Court, Ockenden Road and Gardens, Meadside Highdene properties in White Rose Lane.

PLANNING HISTORY

1999/0475	Erection of an extension to the front elevation to the Pool in the Park reception area to accommodate a fuel cell, and combined heat and power plant cooler. Granted August 1999. The current proposal is an alternative to this scheme

PROPOSED DEVELOPMENT

The purpose of the proposals is to provide a flagship "green" energy scheme which will enable the energy created by the fuel cell, which is to be located adjacent to the Pool in the Park, to produce enough electricity for the Pool in the Park and Leisure Centre However, as the fuel cell alone will not produce sufficient power for this purpose, a separate combined heat and power system is also needed, which will require a chimney.

The excess energy created by these means is to be stored in a thermal store, to be used when needed for heating, lighting and water heating in the Pool in the Park and Leisure centre and also export to the National Grid. Pipes carrying hot water and electricity to the Leisure Centre are to cross the Hoe Stream and are to be disguised underneath a new bridge.

There are four main elements to this application: -

Fuel cell. Thermal Store and flue

The fuel cell, thermal store and flue are to be located is adjacent to the northern section of the Pool in the Park building. The fuel cell structure, CHP unit and related plant are to be developed as extensions to the existing structure wrapping around the north easterncorner of the Pool building, essentially, the area adjacent to the existing plant room is to be extended at ground floor level by an area amounting to about 157 sq. metres in all.

The fuel cell will be on the northern elevation, adjacent to the flumes, and occupying an area at ground floor only measuring 7.5 metres square. It is to be covered in profiled steel cladding and will have a glazed acoustic screen to provide a viewing point An information board will be mounted adjacent to the main thoroughfare to provide information on the fuel cell. Adjacent to the fuel cell is the electrical room, again on the ground floor only, measuring 9.5 metres in width by 3.5 metres in depth.

The existing engine room, RMU (Ring Main Unit connection) room and transformer room, which are situated mainly along the eastern elevation, are to be extended by an area amounting to 35 sq. metres , with a further floor added. In addition, plant is to be located on the roof; this is to be screened by cladding panels to match that existing, which will be visible from the eastern elevation.

The thermal store may be likened to a cylindrical, domed, 'silo' in appearance. It is to measure 9.5 metres in height and 4.5 metres in diameter and is to be located adjacent to the external flumes, in a location which is part of the an access area to the rear of the Pool. it is to be coloured to complement the block-work of the Pool in the Park building, with pipework situated to the rear of the vessel,

The 27 metre high flue is to be within the main structure of the building, close to, and in approximately the same position as the existing outflow pipes from the heating system It is to exit from the engine room and project in front of the existing cladding on the eastern elevation so that the net projection above the roofline is approximately 18 metres.

Plant on the roof of the Leisure Centre

There is also to be plant relating to the fuel cell installed on the roof of the Leisure Centre along its western elevation. This will be in the form of four adiabatic (dry air) coolers part of the air conditioning system each measuring 6.5 by 2 metres- and about 1.8 metres in height. These are to be screened by a frameless louvre system and coloured to match the existing cladding colour at high level.

New Footbridge across the Hoe Stream

In order to carry the services from the fuel cell and CHP plant to the Leisure Centre it is proposed to construct a new bridge across the Hoe Stream, at a point about 35 metres to the west of the existing footbridge which connects the paths to the east of the Leisure Centre and Pool. The pipework will be hidden underneath a new pedestrian footbridge. It will be about 16.5 metres in width with brick piers at either end and decking and railings. It will be supported by concrete footings to be inserted into the stream bed.

A new footpath link in Woking Park

The fourth element is the provision of a new footpath link from the proposed new bridge across the green to the north of the bridge, linking up with the existing path at a point about 35 metres to the north. The existing footbridge and footpath access to it is to be retained in its current position. There is also to be a new footpath link provided connecting the accesses to the existing and proposed bridges. In order to facilitate the construction of the extension, it will be necessary to remove an existing footpath which runs from the avenue alongside the engine room.

CONSULTATIONS

Environment Agency	No objections
Head of Engineering and Streetcare Services	No objections
Chief Environmental Health Officer	No objections
Arboricultural Officer	No objections subject to amendments and conditions.

REPRESENTATIONS

Three letters of representation have been received. The main points may be summarised as follows:

1. The proposed flue is objectionable both from the point of view of its effects on the visual amenity of the Park and with regard to the emissions from it, which could be highly noxious. (Note: The Chief Environmental Health Officer has no objections.)

2. The footbridge would mean a further unnecessary construction of an urban green space and would be detrimental to the free movement of wildlife.

3. The re-routing of the footpath away from the existing footbridge will remove the most direct route to Woking town centre and the station. (Note: The existing pedestrian routes are largely preserved.)

4. The siting of the proposed footbridge is isolated and shut in, making it visually unattractive and unsafe. (The amended proposals show the footbridge reposition).

5. The money spent on this project would be better spent on preventing flood damage.

APPLICANTS POINTS

The applicant has submitted a detailed statement in support of the proposals.

The Planning Application

The planning application comprises two combined heat and power (CHP) elements, the Fuel Cell CHP and a reciprocating CHP. It seeks to address primary energy plant replacement and environmental improvement issues in the Pool in the Park, Leisure Lagoon, Leisure Centre and Woking Park.

Fuel Cell CHP Building

The construction of the fuel cell compound and utility services screening, CHP/absorption chiller plant room and enclosure, technology information/sponsorship display, is located to the rear of Pool In The Park adjacent to the goods delivery bay opposite the Chestnut Avenue/putting green area.

Fuel Cell CHP Technology

A fuel cell is similar to a battery except that fuel in the form of hydrogen and oxygen is fed into the cell to generate electricity and heat by an electro-chemical process without any form of combustion. Natural gas is reformed into hydrogen gas and oxygen is extracted directly from outside air. The clean exhaust comprises H_2O, 100% pure water which will be recovered by a water recovery system for use in the buildings.

Reciprocating CHP Technology

Reciprocating engine CHP co-generates heat and electricity displacing the conventional boilers and grid electricity. Although the CHP reduces overall emissions into the environment it requires a flue to disperse the combustion products (similar to conventional boiler systems).

Heat Fired Absorption Cooling

Chilled water is generated by hot water through a process of absorption at very low pressure which causes the water to boil at 2°C. Heat is provided by the CHP and green electricity is therefore generated from the requirement for cooling as well as heat. Absorption cooling is environmentally benign and displaces ozone depletion and greenhouse gases (CFC's, HCFC's and HFC's) since water and liquid salt is used as the refrigerant.

Environmental/Sustainability

The project will reduce carbon dioxide CO_2 emissions by 12,070 Tonnes p.a. and will displace all CFC and HCFC ozone depletion/greenhouse gas refrigerants used by existing air conditioning plant in the buildings as well as avoiding the need to provide conventional air conditioning chillers and boilers in the Woking Park complex. There are eleven existing gas boilers within the Pool in the Park and Leisure Centre; eight of these will be displaced by the CHP Scheme.

Initially, the surplus electricity will be exported over public wires to other Council buildings to reduce the Authority's exposure to the Climate Change Levy, but as the Thameswey systems grow other local businesses and residential customers can be supplied in this way within the deminimus limits of the Exempt Licensing regime which is currently being reviewed by the Government Priority will be given to supplying surplus green electricity to sheltered housing residents as part of the Council's tackling fuel poverty strategy.

The project therefore, minimises the consumption of energy and pollution by not only making Woking Park self sustaining in green electricity but also supplying other local buildings with surplus export power as well as reducing electricity consumption from the national grid. The fuel cell technology also has the potential of generating 633,000 litres p.a. of clean water and will provide a good educational example of a new green technology working in a real operational environment as an illustration of the possible future hydrogen economy.

Other sustainable development themes will also be addressed such as encouraging a strong and diverse local economy, meeting local needs through the 'proximity principle', promoting health, equality and local well-being through tackling fuel poverty,' encouraging opportunities for education and information through the technology information/sponsorship display, opportunity to be part of the community through local sustainable community energy systems and accentuating features which contribute to Woking's Pride of Place through building on Woking's national and international reputation in energy efficiency.

The plant room for the Fuel Cell and CHP is not in the flood plain and a new foot bridge across the Hoe stream will improve accessibility within the park.

Technical Design Criteria

The Applicant has sought advice from specialist consultants and undertaken consultationwith the Councils Environmental health officers in order to identify the controlling criteria for these conditions. During the course of preparing the application technical guidance on the influencing factors for the flue height were obtained. These were the Clean Air Act 1993, DETR Good Practice Guides 116 and 234, the National Air Quality Strategy, The Environmental Protection Act 1990 and The Environment Act 1995.According to DETR Good Practice Guide 234 Guide to Community Heating and CHP and the DETR Guide 116

Environmental Aspects of Large-Scale Combined Heat and Power chimney heights are determined by a wide range of factors including the exhaust contents, the background air quality, the temperature and velocity of the exhaust and the topography of the local area which would include the adjacent Park, Leisure Facilities and surrounding residential dwellings.

However, erecting a chimney has a visual impact on the surrounding area and the height has therefore been minimised to what is necessary to achieve dispersal of combustion products as well as utilising the cleanest practicable combustion technology and low sulphur fuels.

The advice received to date, indicates that the relevant legislation and guidance notes for a CHP of this size (1.35 MWe) are contained in the Clean Air Act 1993, DETR Good Practice Guides 116 & 234, HMIP Technical Guidance Note (Dispersion) D1, the National Air Quality Strategy, The Environmental protection act 1990 and The Environment Act 1995.

In order to provide appropriate noise control of the CHP plant an acoustic plenum has been provided at ground floor level within the building. This plenum will contain sound attenuators which will reduce noise on the exterior of the building to decibel levels to within 2dB of the prevailing background noise in the area. Particular note has been made of the proximity of the residential areas adjacent to the park and Leisure Facilities, when calculating the appropriate attenuation requirements. The applicants supporting acoustic specification forms part of the application documents.

The adiabatic coolers which are located at roof levels on the CHP station at the Pool in the Park and Leisure Centre, have been selected to comply with the same attenuation standards.

The prominent nature of the site has suggested that the exhaust flue should be kept to an acceptable minimum height, commensurate with the legislative requirements referred to above. The calculations accompanying this submission have established the height of the chimney at 27 metres above ground level. The appearance of the proposed flue is illustrated on the application drawings. The nature of natural gas fired CHP stations means that they produce less emissions than conventional plant rooms and particularly reduced CO2 emissions (as indicated in the accompanying spread sheet) contributing towards the UK's Kyoto (Climate Change) and CHP Strategies. The design currently proposed will provide noise and emission control to acceptable standards. The development of the station will enable the applicant to supply energy to the Pool in the Park, Leisure Centre, Park Lighting Scheme and other Buildings in the Park as well as exporting electricity to other nominated sites in a more efficient and environmentally friendly manner than previously possible.

In order to allow construction of the CHP station it has been necessary to remove a small section of footpath to the rear of the Pool in the Park but the new footpaths and a new bridge over the Hoe Stream will enhance accessibility through the park and more than compensate for its loss.

RELEVANT PLANNING POLICIES

Local Plan 1999: Policies NE6, NE9, NE11, BE1, BE6, BE7, CUS8, CUS9

ENVIRONMENTAL IMPLICATIONS

The proposal is for an environmentally sustainable means of powering and heating the Pool in the Park, which will allow the complex to become almost self sufficient. However, the location of the proposal is very sensitive in visual terms and also has implications for trees.

PLANNING ISSUES

Principle

Policies CUS8 and CUS9 of the Local Plan encourage proposals for the development of renewable energy resources where there would be no material harm to the environment by reason of location, noise, appearance or traffic generation and would not result in loss of land protected by other policies in the Plan. CHP stations are to be generally permitted. The principle of the development is therefore to be supported subject to normal environmental and planning considerations.

Visual Impact on the Park

Policy NE6 specifically seeks to protect river corridors from development which would have a detrimental impact on the landscape quality, NE9 relates to the requirement to protect trees within development proposals, and BE7 offers protection to Urban Open Space, allowing development proposals only where they would not compromise the character of the site.

The proposed development will introduce highly visible features to the landscape of the Park, and the impact of these has to be assessed against the criteria of Policies NE6, and NE7, in particular the issue of whether the proposed development would compromise the character of the site.

The fuel cell and thermal store are situated in an area which is already occupied by plant and service rooms, and also the flumes, which are a very high profile feature in this area of the Park. As such, the proposed additions will be consistent with the type of use which is located in this area at present. The design, materials and scale of the additional accommodation will allow the extensions and the thermal store to blend in with the general character of this area better than would be possible elsewhere in the Park.

Moreover, the proposed location of these facilities is such that it will not be seen by the large numbers of visitors who arrive at the Leisure Centre by car, although they will be clearly in evidence to pedestrians using the avenue to the north of the Pool.

The 27 metre high flue, necessary for the CHP unit, is to be coloured goosewing grey, and will be about 0.6 metres in diameter and will be seen from a wide area around the boundaries of the Park. This will introduce a new element into the park environment; however, there are factors which should be taken into account:

- the design of the pool is modern and has vertical detailing which would help the flue read as part of the building;
- it is a slender flue at 0.6 metres in diameter;
- it would be coloured 'goosewing grey', a colour often used to soften the appearance of such structures; and
- the trees in the park provide limited screening.

The flue is necessary if the CHP is to proceed and whilst it will be visible it is not considered to be unduly so, due to its slender construction.

With regard to the visual effects of the new plant on the roof of the Leisure Centre, this will be barely visible from ground level when viewed from most angles, and will blend in with plant which already is already in position on the Leisure Centre roof.

It is considered that the appearance of the bridge, being constructed from natural materials which are consistent with those used for the nearby bridge, is acceptable, and will cause no detriment to the character of the Park. As such, it is consistent with the requirements of Policies NE6 and BE7 of the Local Plan.

<u>Impact upon trees</u>

The proposed extension to the engine room is in close proximity to the blue cedar (Cedrus Atlantica Clauca) in particular, which is one of the most notable specimens in the Park. The plans for the plant associated with the fuel cell have been amended so that this part of the extension is now a full 2 metres clear of the crown of the blue cedar to allow for the building works and its future growth. The proposed re-positioning of the proposed new bridge and footpath links now avoids any adverse effect on trees, as both have been positioned to avoid the removal of any trees apart from one weeping willow, which is not a good specimen in any event. The proposal is therefore considered to be acceptable in this respect.

<u>Alterations to pedestrian links in Woking Park</u>

The reference to the turfing over of the footpath has now been deleted from the plans, so the situation will remain as it is at present, although there will in future be a choice of two bridges in close proximity to each other which will not affect established pedestrian routes through the Park. With regard to the deletion of the path which runs adjacent to the Engine Room, this is merely a link which cuts off a corner, and no adverse consequences or inconvenience will result from the removal of this path.

<u>Impact upon neighbours</u>

The development is well divorced from immediate residential occupiers and as such the visual impact is minimal. With regard to noise, again the Environmental Health Officer confirms that with appropriate attenuation, there should be no significant noise impact on residential properties in the vicinity. The noise implications are to be controlled via suggested condition 5.

<u>Other Considerations</u> \

Concern has been expressed by residents at the possibility of noxious emissions from the proposed flue. Whilst the nature of the emissions is not a planning issue, it is nonetheless useful to comment in order to dispel any concerns that neighbours might have. It is clear from the applicant's supporting statement that the only emissions from the fuel cell are water and negligible combustion gases. The Environmental Health Officer confirms that the height of the chimney conforms to the air quality legislation. He also points out that the emissions emanating from the proposed installation will result in considerable energy savings and hence emission reductions compared to the existing situation; effectively the proposal is 'cleaner' than the existing.

CONCLUSIONS

The proposals will clearly have a visual impact on this area of the Pool in the Park; however the impact is reduced given the location of the new buildings in the context of the existing structures and landscaping. In any event the proposals meet several of the key objectives of the Local Plan with regard to the encouragement of energy efficient projects and Combined Heat and Power schemes. On balance, it is concluded that the proposal is acceptable.

BACKGROUND PAPERS

1. Memo from Environmental Health Officer dated 8/5/01.
2. Memo from Arboricultural Officer dated 27/4/01 and 8/5/01.
3. Memo from Landscape and Countryside Officer.
4. 3 Letters of representation.
5. Memo from Head of Engineering and Streetcare Services dated 4/4/01
6. Building Services Officer technical justification, assessment of CO, emission savings, Environmental Noise Survey Report, and Stack Height calculations.
7. Letter from Environment Agency dated 8 May 2001 +

RECOMMENDATION

It is recommended that planning permission be Approved subject to the following

conditions:-

1. C004 Standard Time Limit
   R004

2. C051 Tree Replacement for felled willow.
   R051

3. C054 Protective Fencing for trees.
   R054

4. C056 Ground Levels/Excavation Within Protective Tree Fencing
   R056

5. All plant to be installed, screened and housed to ensure noise from Building Services and Plant, are at least 5dBA below the prevailing background noise level (LA90) when measured from the window of the nearest noise sensitive property and the equipment will be operated at this standard thereafter.

   Reason: In the interests of the amenities of neighbouring dwellings.

6. No spoil or materials shall be deposited or stored on that part of the site lying within the area of land liable to flood.

Reason: To prevent the increased risk of flooding due to impedance of flood flows and reduction of flood storage capacity.

7. No building or raising of ground levels shall take place on that part of the site lying within the area of land liable to flood.

Reason: To prevent the increased risk of flooding due to impedance of flood flows and reduction of flood storage capacity.

8. Any walls or fencing constructed at the site, within the area of land liable to flood, shall be designed to be permeable to flood water.

Reason: To prevent the increased risk of flooding due to impedance of flood flows and reduction of flood storage capacity.

9. The footbridge across the stream shall be constructed so as to span both banks with the abutments set back from the watercourse on the bank tops and shall allow for a margin of bank underneath.

Reason: To maintain the character of the watercourse and provide undisturbed refuges for wildlife using the river corridor.

{Note: The Environment Agency asks to be consulted on any details submitted in compliance with this condition}.

10. No soakaways shall be constructed such that they penetrate the water table and they shall not in any event exceed 3 metres in depth below existing ground level.

Reason: To prevent pollution of groundwater.

Informatives

1. D001 Drawing Numbers

02373/02 Rev B, 01373/-20-1/1 Rev B, 01373/03 Rev B, 01373/04, 01373/05, 01373/06 dated 6/3/01, received 20/3/01, 9/4/01, 8/5/01, 9/5/01.

2. D041 Construction which is audible at the site boundary is limited under the Environmental Pollution Act to 0800-1800 Monday to Friday and 0800- 1300 Sunday and not on Bank or Public Holidays.

3. D013 Relevant Local Plan Policies

NE6, NE9, NE11, BE1, BE6, BE7, CUS8, CUS9

4. Under the terms of the Water Resources Act 1991 and the Land Drainage Byelaws 1981, the prior written consent of the Environment Agency is required for any proposed works or structures in, under, over or within 8 metres of the brink of the Hoe Stream main river.

5. Under the terms of the Water Resources Act 1991, the prior written consent of the Environment Agency is required for any discharge of sewage or trade effluent into controlled waters (e.g. watercourses and underground waters), and may be required

for any discharge of surface water to such controlled waters or for any discharge of sewage or trade effluent from buildings or fixed plant into or onto ground or into waters which are not controlled waters. Such consent may be withheld.

6. The proposed new footbridge will require Environment Agency consent under the Water Resources Act 1991 and land Drainage Byelaws 1981.

7. Attention is drawn to the Environment Agency's letter dated 8/5/01. The applicant is requested to address all other issues raised in this letter.

APPENDIX 3
Synopsis of the Specification for the Engineering Works Involved in the Project.

(i) Phase 1A - Woking Park Fuel Cell CHP

(a) Fuel Cell CHP Enclosure

Construction of the fuel cell CHP enclosure, including all structural and civil engineering works, building works, acoustic screening, services, high frequency lighting and power, enclosure floodlighting, landscaping, external works and treatment works, etc., to accommodate the fuel cell CHP and associated cooling module on a purpose built slab and the associated switchgear, control gear and monitoring.

(b) Technology Information/Sponsorship Display

Technology information and sponsorship display encompassing brief simple layperson's descriptions of the Council's Thameswey concept, fuel cell CHP, absorption cooling and photovoltaic technologies with coloured graphics/ diagrams as well as details of the sponsors and official opening.

(c) Fuel Cell CHP Installation

Fuel cell combined heat and power installation, low noise cooling module, high-grade heat exchanger and independent grid option, including the supply and installation of all other plant, equipment, switchgear, control gear, cabling, interconnecting pipework, RADAR and call out engineer telephone lines, nitrogen installation, plume suppression, mains water and drain connections, etc.

(d) Delivery, Transportation and Off-loading to Site

Delivery, transportation, all import taxes, duties, insurance, licences, permits etc., and off-loading to site of the fuel cell CHP and associated equipment.

(e) CHP Services

CHP Services, including gas supply, distribution, low and high-grade heat mains and private wire to/from the fuel cell CHP.

(f) Water Recovery from Fuel Cell CHP

Water recovery from the fuel cell CHP, including plume suppression, water recovery, water treatment, sampling tap, water meter and utilisation as a supplementary water supply source to the Pool In The Park.

(g) Monitoring

Monitoring installation, including monitoring equipment, ONSI RADAR system and interface with the existing BEMS.

(ii) Phase 1B - Woking Park CHPC

(a) Extension to Fuel Cell CHP Enclosure

Extension of the fuel cell CHP enclosure, including all structural and civil engineering works, building works, acoustic screening, services, high frequency lighting and power, enclosure floodlighting, landscaping, external works and treatment works, etc., to accommodate the heat fired absorption chiller plant room (including plant room independent frost protection, standby generator/supply to the fuel cell CHP in the event of an emergency, etc) on an extended purpose built slab and the associated switchgear, control gear and monitoring.

(b) Pool in the Park CHPC

Combined, heat, power and cooling system utilising the fuel cell CHP and existing reciprocating engine CHP, heat distribution and chilled water mains and private wire, including heat fired absorption chiller in the fuel cell CHP enclosure plant room and associated adiabatic coolers on the roof of the Pool In The Park, conversion of existing Competition Pool air handling unit system to provide separate cooling and control to the Pool Hall and Spectators Gallery, new air conditioning system in the Teaching Pool Spectator Area, additional air conditioning system in the Atrium/Reception Area, associated BEMS and controls and heat, chilled water and electricity energy meters, etc.

(c) Leisure Lagoon CHPC

Combined heat, power and cooling system utilising the fuel cell CHP and existing reciprocating engine CHP, heat distribution and chilled water mains and private wire, utilisation of existing electric/refrigerant air conditioning system in the Cafe/Bar to be served by the new absorption cooling system, new air conditioning system in the Flume Tower, associated BEMS and controls and heat, chilled water and electricity energy meters, etc.

(iii) Photovoltaic Solar Shading System

Photovoltaic solar shading system to replace existing glazing in the Spectator Gallery, Reception Atrium and Flume Tower, including adaption of existing rooflights and glazing systems, all structural and civil engineering works, building works, electrical and mechanical services, inverters, electricity connection/G59 protection and associated switchgear, control gear and monitoring/metering equipment.

(iv) Phase 2 – Woking Park CHPC

(a) Leisure Centre CHPC

Combined, heat, power and cooling system to supplement the Phase 1 – Woking Park Fuel Cell CHP system, including conventional CHP, thermal store, heat fired absorption chiller and associated adiabatic cooler, conversion of existing heating and ventilation air handling unit systems into heating, ventilation and air conditioning air handing unit systems, replacement/ utilisation of existing electric/refrigerant air conditioning systems in the Restaurant, Bar and Crèche to be serviced by the new absorption cooling chilled water supply, associated BEMS and controls and heat, chilled water and electricity energy meters, etc.

(b) CHP Services

Combined heat and power services, including distribution heat mains and private wire between the Leisure Centre and the Pool In The Park.

(v) Maintenance and Operating Instructions, Record Drawings and Training

Provision of maintenance and operating manuals, record drawings and manufacturer's and on site training of nominated personnel.

(vi) Labels, Circuit Lists/Diagrams, Testing, Inspection and Commissioning

Labels, circuit lists/diagrams, testing, inspection and commissioning of Phases 1A and 1B systems electrical and mechanical installations and associated systems (including the fuel cell CHP and associated cooling module, high-grade heat exchanger and grid independent option, liaison with others and co-ordination of all services and commissioning provided by others, contained and/or connected with this Specification).

(vii) Comprehensive Maintenance

Provision of comprehensive maintenance, including planned preventative, breakdown and repair maintenance/call-outs.

APPENDIX 4
Report by Allan Jones MBE on Visit to UTC Fuel Cells in August 2001

Each fuel cell resembles a black/dark grey heavy-duty carpet tile approximately 750mm^2 square with the anode to one side and the cathode to the other side, with the matrix between. Phosphoric acid is dripped onto the matrix from a drip wire along a production line and is blotted up by the matrix. This forms the fuel cell.

The fuel cells are then assembled with a thin flat cooling module between each stack of eight plates, known as sub-stacks. There are 34 sub-stacks, held together by vertical manifolds bolted at the corners, with each PC25 therefore containing 272 fuel cells. The whole fuel cell stack is then enclosed in a jacket. The amount of platinum in the PC25 costs between $30 and $40 per kW. No other exotic materials are used, graphite being the main material.

Following the experiences of customers UTC fuel Cells had recently increased the thermal energy output specification from 700,000 BTU/h (205 kW) to 900,000 BTU/h (264 kW) for the same gas input. In some instances, customers had achieved up to 1,000,000 BTU/h (293 kW) where all of the low-grade heat is extracted and utilised. The increase in thermal efficiency reduces the electrical efficiency to 37% but increases the overall efficiency from 85% to 90%.

The grid-independent option changeover from grid supply operation to independent (or island mode) operation takes ¼ cycle (0.005 seconds) which is acceptable as an interruptible supply and significantly improves the attractiveness of the PC25 as a black start generator for larger machines. Conventional black starts typically take 11 to 12 seconds to re-synchronise the generator, during which time supply is lost.

Although UTC Fuel Cells had not previously considered the Unit in this role, a PC25 in conjunction with a 1 MW CHP was due to be commissioned in Connecticut in late 2001. UTC Fuel Cells had not realised the PC25's potential as a black start generator for what is a completely new market in power station support, in island generation mode. This is particularly relevant for the Utility's own generation and critical supply customers, in addition to independent generators/suppliers such as the Woking Borough Council or Thameswey, operating on private wires in the emerging deregulated energy markets.

UTC Fuel Cells showed interest in the Council's proposal to recover and utilise the exhaust water since no one had ever done this before (other than in spacecraft). UTC Fuel Cells confirmed that the exhaust water was 100% pure. UTC Fuel Cells suggested that the recovered water could be put through the filter system in the PC25 but a better solution would be to provide an external filter.

A fuel cell stack replacement currently costs $300,000. Alternatives to this were a reconditioned stack or removing an existing stack and sending it back to UTC Fuel Cells for reconditioning, although the cell stack voltage would not quite be as good as a new stack.

The 24-hour engineering support for PC25's is provided free by UTC Fuel Cells. Each PC25 is linked back to UTC Fuel Cells using the Rockwell software and the customer is required to provide two telephone lines from the PC25, one to be used for the modem link to UTC Fuel Cells and one to be used by maintenance engineers on site so that they can view the same data on line as UTC Fuel Cells and be directed by its engineers to fault find and repair.

A remote standby supply should also be provided by the customer for the fuel cell stack heater in the remote possibility that the PC25 shuts down in the winter at the same time as a power disruption. This is intended to prevent freezing of the fuel cell stack

UTC Fuel Cells confirmed that it was developing polymer electrolyte (PEM) fuel cells for the light commercial/residential and transport markets. The light commercial / residential fuel cell operates on natural gas or propane and either independent of or connected to the grid. Grid connected units provide base load power and heat with the utility providing the short-term peak power. Should a power cut occur, the fuel cell would convert to grid-independent operation instantaneously and maintain power for critical building loads. The unit will have long periods between maintenance. UTC Fuel Cells advise that this unit will be available in early 2003.

For transportation the PEM cells offer the promise of a zero emission vehicle with an energy efficiency twice that of the internal combustion engine but without the range limitation of battery powered cars. UTC Fuel Cells is working with major auto and bus companies to design and manufacture fuel cells for transportation applications and have already built the Hyundai Santa Fe and the Thor bus.

UTC Fuel Cells is also working on a PEM cell replacement for the PC25 to be known as the PC35, and which will be rated at between 150 and 200 kW. UTC Fuel Cells research in the USA seems to favour a 150 kW model but does not take into account the growth of independent generators / suppliers in the emerging deregulated energy markets such as Woking Borough Council or Thameswey, where larger fuel cells may be more attractive. The PC35 fuel cell stack is being designed in such a way that it would be possible to utilise it as a slot-in replacement fuel cell stack for the PC25. UTC Fuel Cells advise that the anticipated cost of the PC35 will be one third of the cost of the PC25.

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The Hydrogen Fuel Cell

The principle of hydrogen fuel cells was first demonstrated by a British scientist and judge **Sir William Grove** in 1839. He discovered a relatively straightforward electro-chemical process where hydrogen and oxygen interact within a cell to generate electricity and heat.

The fuel cell contains an anode and a cathode with an electrolyte sandwiched between them, separating the two. Hydrogen is supplied into the anode and oxygen into the cathode. The two gases want to join but are prevented from doing so by the electrolyte which causes the hydrogen to split into a proton and an electron. The proton passes freely through the electrolyte whilst the electron is forced to take a different route around it, creating an electric current before re-combining with the proton to make hydrogen again and combining with oxygen through a catalyst, creating a molecule of water.

There are several different types of fuel cell that work on this principle, each using a different material for the electrolyte (alkaline, phosphoric acid, molten carbonate, solid oxide and solid polymer or proton exchange membrane). Each operates at different temperature ranges and is suitable for different applications within stationary or portable power, or transport. The hydrogen fuel cell used on the Woking Park —Fuel Cell CHP project is a phosphoric acid fuel cell.

Since GroveÕs experiments, the technology has been developed intermittently facing opposition from the prevailing Hydrocarbon Economy, and it was not until the 1960Õs space programme that fuel cells were used in a real practical environment. UTC International Fuel Cells (who make the alkaline fuel cells for the NASA Space Programme) produced the first commercial stationary phosphoric acid fuel cells in the early 1990Õs and more recently other manufacturers have produced commercial fuel cells for the emerging residential CHP and transport markets.

Father of the Fuel Cell: Sir William Robert Grove

Grove biography supplied by the World Fuel Cell Council. Based on papers and manuscript drafts held at the Royal Institution, and other archives.

The ÒFather of the Fuel CellÓ, Sir William Robert Grove was born the son of a magistrate in 1811 in Swansea, South Wales. He received elementary schooling from private tutors, and graduated with a bachelorÕs degree from Brasenose College, Oxford, in 1832. Following his fatherÕs footsteps, Grove then embarked on a notable career in Law, whilst simultaneously devoting himself to his life-long passion of scientific exploration and electrochemistry in particular.

He became a barrister at LincolnÕs Inn in 1832 and made more than a comfortable living within the legal profession, often taking high profile cases (such as that of Dr William Palmer —hanged in 1856 —better known as ÒThe Rugeley PoisonerÓ or ÒThe Prince of PoisonersÓ) .

Despite occasional over enthusiasm —Grove often got so sidetracked in patent cases that he would himself suggest design enhancements to new products during the hearing —his practice grew quickly, and after retiring as a barrister (partly due to his health) in 1853 he became a QueenÕs Council (QC). He became a member of the Royal Commission on the Law of Patents in 1864, and was made a Judge of the Common Pleas in 1871. After receiving his knighthood in 1872, Grove then became a Judge of the QueenÕs Bench in 1880 and a Privy Councillor in 1887.

Grove devoted even more of his time to the Sciences after his semi-retiring from the legal profession (in 1853), though did much of the work for which he is remembered —including his Ògas batteryÓ fuel cell —prior to this.

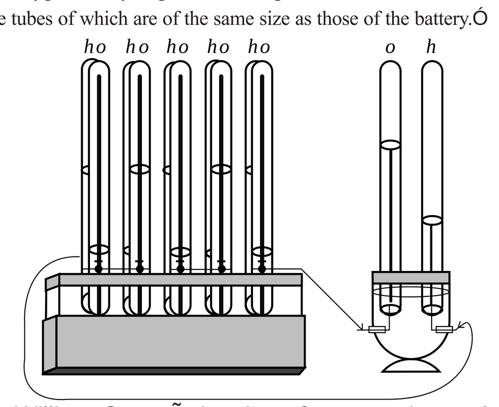
In 1837, Grove married Emma Powles, who subsequently bore him six children. It was two years later, in 1839, that we look to today as the moment the fuel cell was born in the laboratories of the London Institution at Finsbury Circus. The following year he was appointed to the professorship of experimental philosophy at the London Institution.

Seemingly anticipating todayÕs electric lighting back in the 1840s, Grove did much to enhance his reputation as an experimentalist/inventor after lighting the entire theatre at one of his lectures with incandescent electric lamps with platinum filaments, powered by a battery of his nitric acid cells.

So too in the realm of physics, Grove proved ahead of his time. His ÒThe Correlation of Physical ForcesÓ, published in 1846, proposed the fundamental concept of the mutual convertibility of ÔforcesÕ [energy].
In the same year Grove (who was elected a Fellow in 1840) was officially recognised by the Royal Society who awarded him a Royal Medal for his Bakerian Lecture on ÔCertain phenomena of voltaic ignition and the decomposition of water into its constituent gasesÕ. He served as a Member of the Council and then as Secretary of the Royal Society, and was a lifelong Member of the Royal institution of Great Britain and the Chemical Society.

He died an old man of 85 in 1896 at his family home on St Annes Hill in Wandsworth, South London.

Fortuitously, Grove provided copious detailed documentation of his experimentation and discussions with his scientific peers —including his friend and colleague Michael Faraday. The illustration below was originally extracted from correspondence with the Swiss theoretical scientist, Christian Schoenbein, to whom he wrote in 1843: ÒIn figure 6, a battery of five cells ... is represented as when charged [filled] with oxygen and hydrogen, and having been for some time connected with the voltmeter (figure 7), the tubes of which are of the same size as those of the battery.Ó



William GroveÕs drawing of an experimental Ògas batteryÓ from an 1843 letter

Image from *Proceedings of the Royal Society*

The electrolysis of water was first demonstrated in 1800 by British scientists William Nicholson and Anthony Carlisle. But combining hydrogen and oxygen to produce electricity and water was, in GroveÕs words: Òa step further that any hitherto recorded.Ó He discovered that a constant electric current would flow between two platinum electrodes if each electrode had one end immersed in a common container of sulphuric acid, and the other separately sealed in containers of hydrogen and oxygen. Furthermore, he noted that the volume of water also held in the glass gas tubes increased as the current flowed.

Grove wrote, Òten cells charged to a given mark on the tube with dilute sulphuric acid ... oxygen and hydrogen, were arranged in circuit with an interposed voltameter ... and allowed to remain so for thirty-six hours. At the end of that time 2.1 cubic inches of mixed gas were evolved in the voltameter; the liquid had risen in each of the hydrogen tubes of the battery to the extent of 1.5 cubic inch, and in the oxygen tubes 0.7 cubic inch, equalling [sic] altogether 2.2 cubic inches; there was therefore 0.1 cubic inch more of hydrogen absorbed in the battery tubes than was evolved in the voltameter. This experiment was repeated several times with the same general result.Ó

Grove produced several variations upon this device, which he named a Ògas batteryÓ—the first fuel cell.

WOKING PARK – FUEL CELL CHP
The First Fuel Cell Combined Heat and Power System in the UK

Officially opened on 16 June 2003

This fuel cell combined heat and power (CHP) system, the first in the UK, is part of a local sustainable community energy system developed in partnership between the United Kingdom, Denmark and the United States of America. It supplies environmentally friendly green energy to Woking Park and its buildings and even some residents in the Borough of Woking.

The Thameswey Energy Station operates by fuel cell CHP, other CHP and solar energy photovoltaics with heat fired absorption cooling, thermal storage and private wire, heat and cooling distributed energy networks.

By recovering heat from its own power generation (see diagram) CHP is far more energy efficient and much less wasteful than separate traditional energy systems. The Woking Park CHP will reduce carbon dioxide CO_2 emissions equivalent to 9,990 tonnes of greenhouse gases every year. It also eliminates ozone depletion gases used in air conditioning by generating chilled water from hot water through the absorption process.

Developed in partnership with:

Fuel Cell CHP System Sponsored by:

U.S. Department of Defense

National Energy Technology Laboratory Logo

U.S. Department of Energy

Community Energy Systems Sponsored by:

Main Contractors:

Fuel Cell CHP Supplied by:

Fuel Cell CHP Installed by:

Solar Energy Photovoltaics by:

Fuel Cell Mural by:

Alan Potter

Sir William Grove Statue by:

Artist:
Ulli Knall

Foundry:
Nautilus Fine Art Foundry Ltd

Plinth and Installation:
Cathedral Works Organisation (Chichester) Ltd

Sir William Grove Biography Sponsored by:

(based on papers/manuscripts held by the

The Royal Institution of Great Britain)

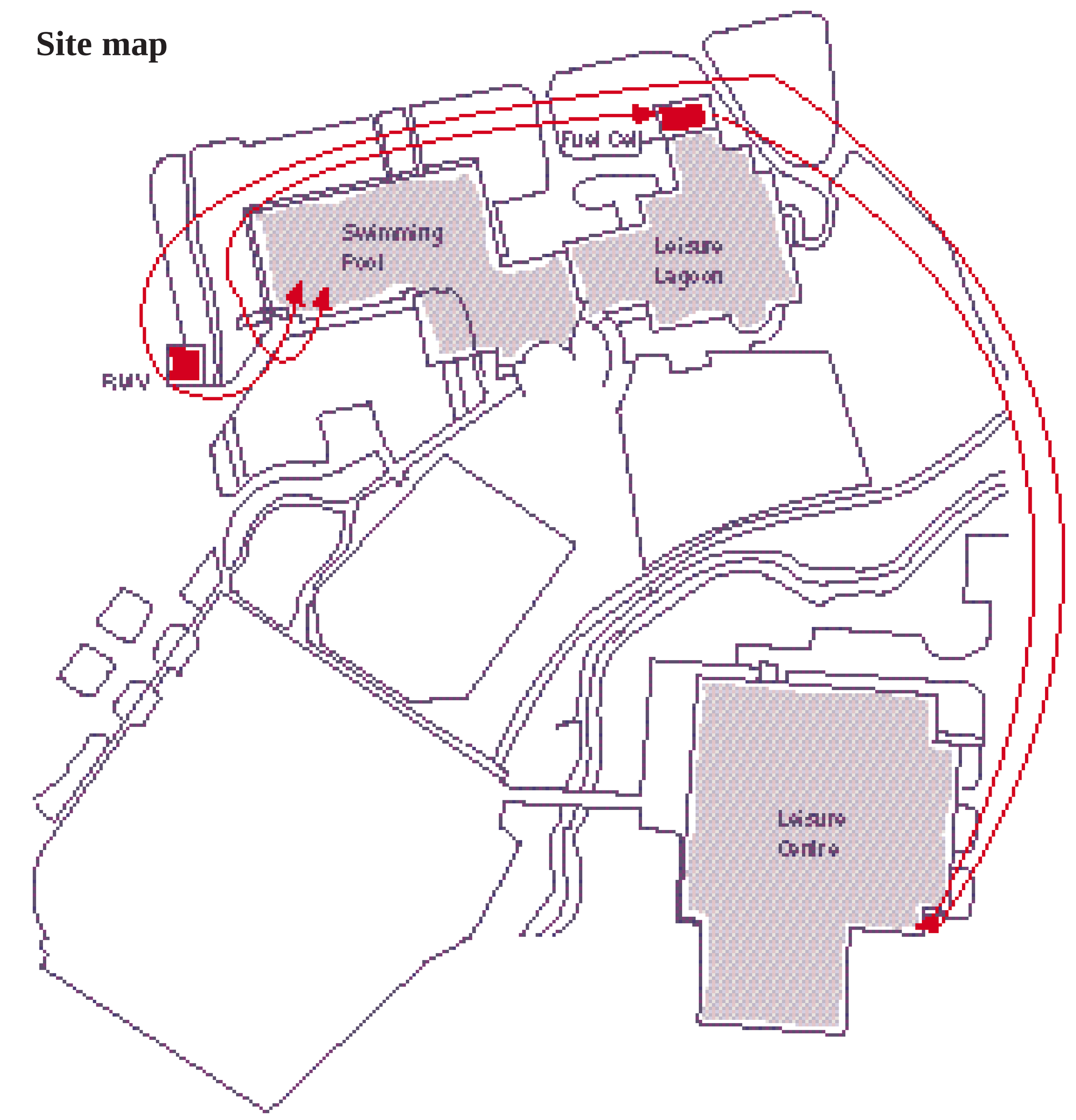
Sir William Grove Statue Sponsored by:

Grove Symposium Steering Committee

Hedeselskabet Logo

WOKING PARK CHP MURAL

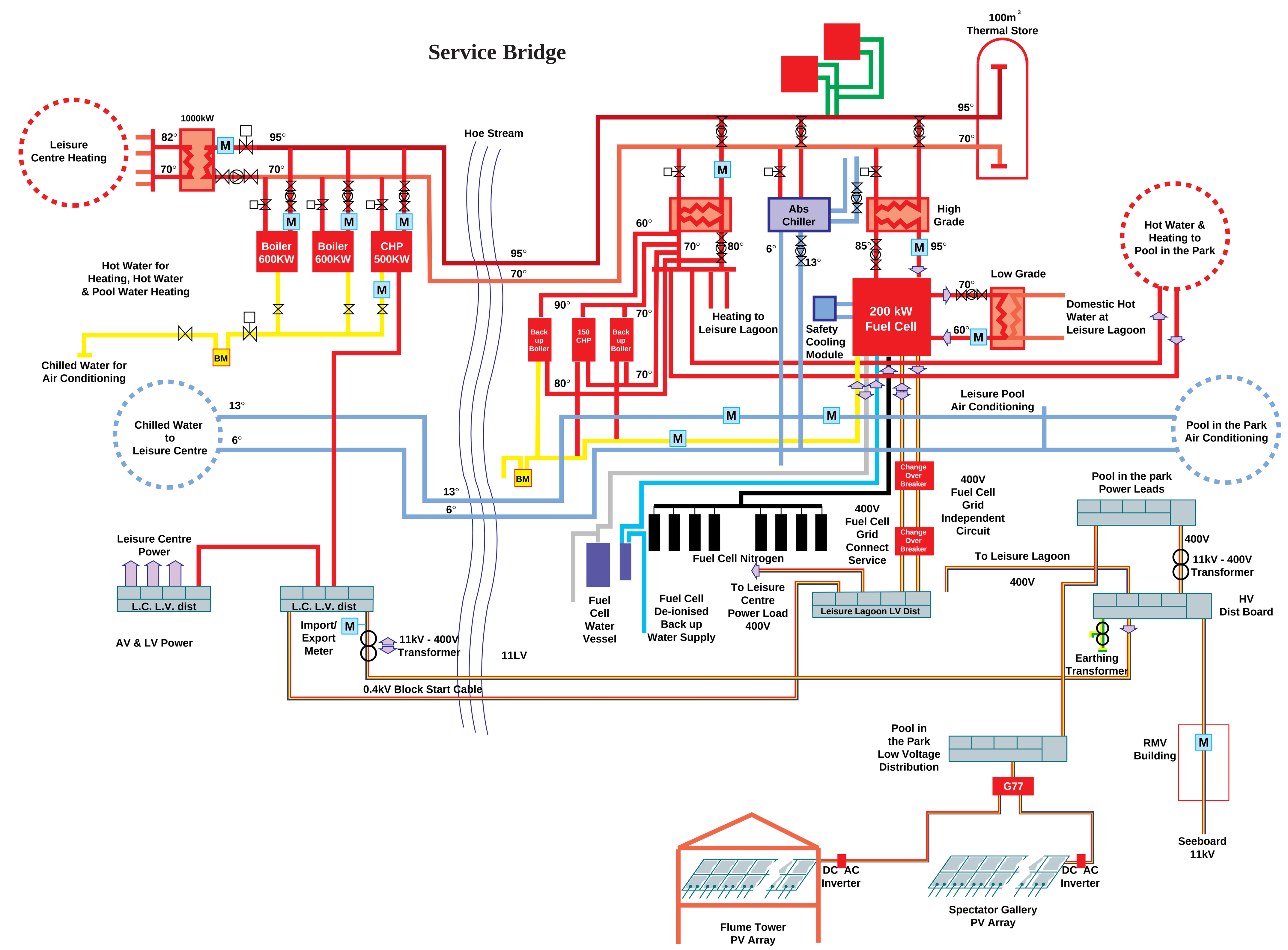
Site map



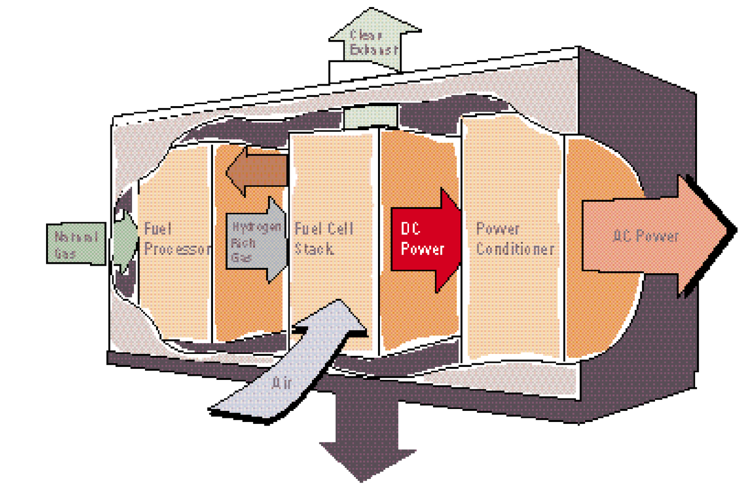
Leisure Centre

Leisure lagoon

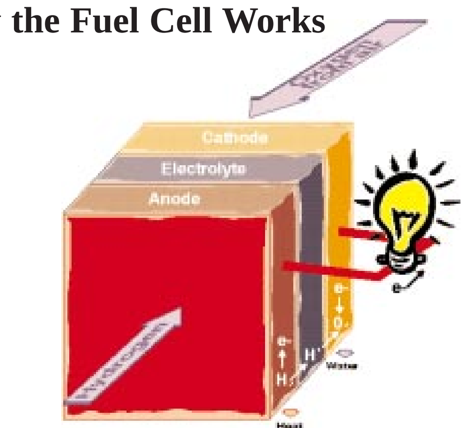
Pool in the Park



Power Plant Subsystems



How the Fuel Cell Works



Fuel Cell Concept

A fuel cell is an electrochemical device that combines hydrogen fuel and oxygen from the air to produce electricity, heat and water. Fuel cells operate without combustion, so they are virtually pollution free. Since the fuel is converted directly to electricity, a fuel cell can operate at much higher efficiencies than internal combustion engines, extracting more electricity from the same amount of fuel. the fuel cell itself has no moving parts - making it a quiet and reliable source of power.

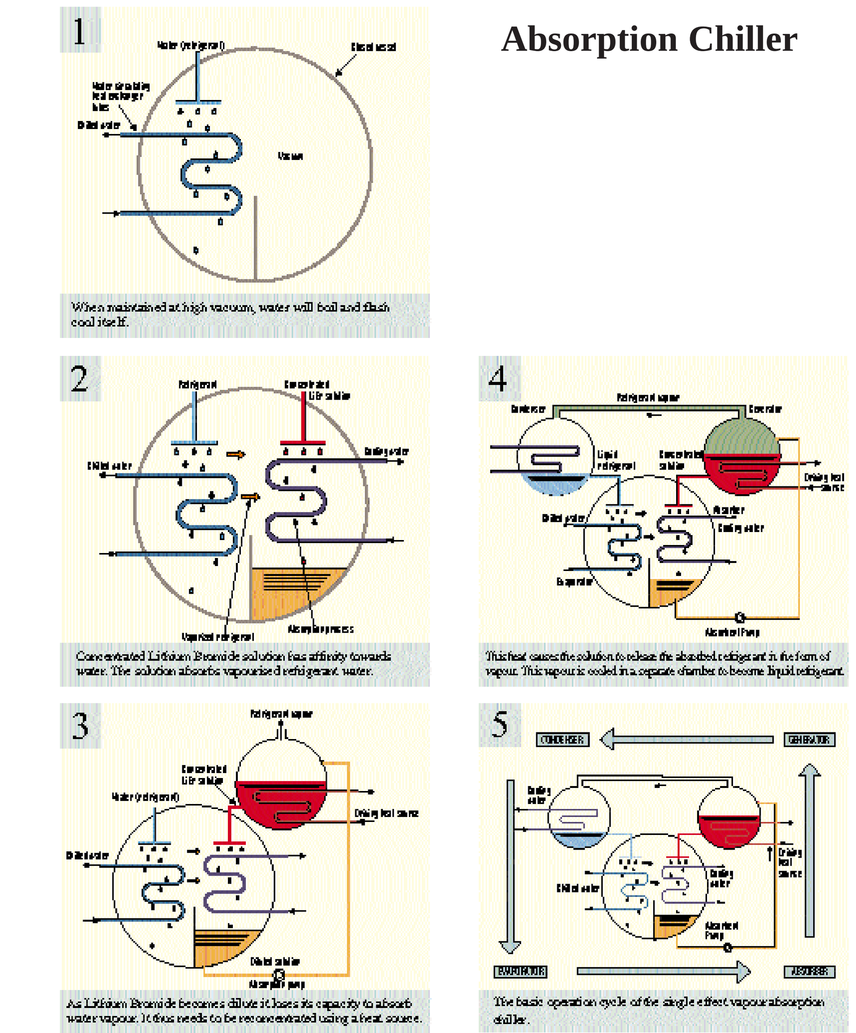
The picture shows how a fuel cell produces electricity. The fuel cell is composed of an anode (a negative electrode that repels electrons), an electrolyte in the center, and a cathode (a positive electrode that attracts electrons).

As hydrogen flows into the fuel cell anode, platinum coating on the anode helps to separate the gas into protons (hydrogen ions) and electrons. The electrolyte in the centre allows only protons to pass through the electrolyte to the cathode side of the fuel cell. The electrons cannot pass through this electrolyte and flow through an external circuit in the form of an electric current. This current can power an electric load, such as the light bulb shown here.

As oxygen flows into the fuel cell cathode, another platinum coating helps the oxygen, protons, and electrons combine to produce pure water and heat.

Individual fuel cells can be then combined into a fuel cell “stack”. The number of fuel cells in the stack determines the total voltage, and the planform area of each cell determines the total current. Multiplying the voltage by the current yields the total electrical power generated.

Absorption Chiller



Basic Principle:

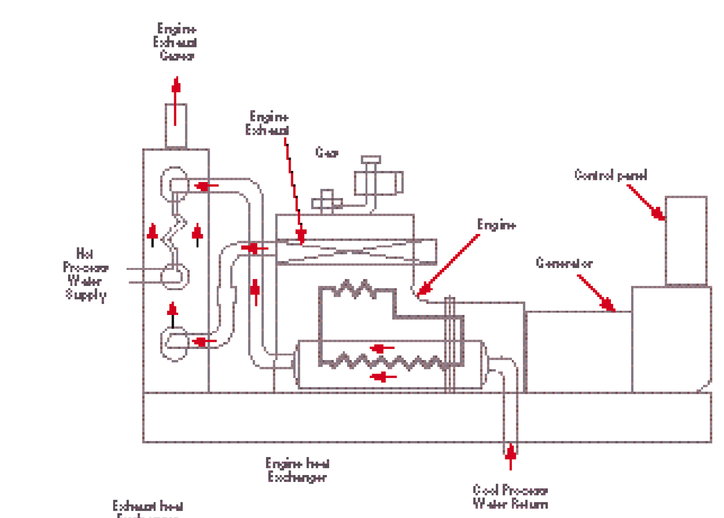
Boiling point of water is a function of pressure. At atmospheric pressure, water boils at 1000C. At lower pressure it boils at lower temperature. The boiling point of water at 6mm of mercury absolute, is only 3.70C.

Lithium Bromide (LiBr) salt has the property to absorb water due to its chemical affinity. it is soluble in water. As the concentration of LiBr increases, its affinity towards water increases the affinity decreases.

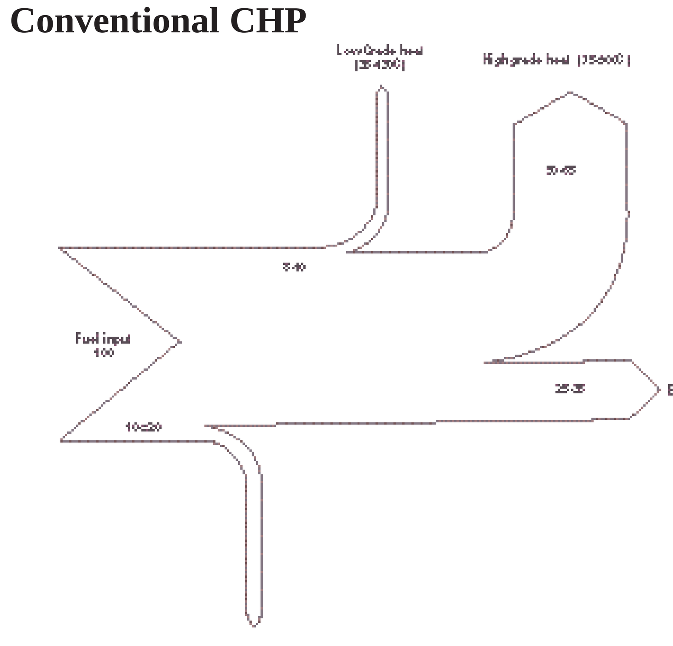
There is a large difference between vapour pressure of LiBr and water.

Operating Principle:

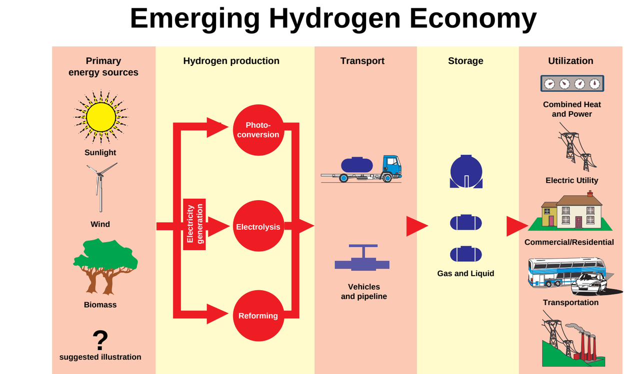
The vapour absorption chiller produces chilled water upto 4.50C, utilising hot water as the driving source. The chiller utilises the latent heat released by the refrigerant (water) as it evaporates (in a closed pressure vessel) for cooling. Unlike a compression chiller which uses a compressor to pressurize the vapourised refrigerant (Freon) and condenses it by using cooling water, the absorption chiller uses an absorbent (LiBr) to absorb the vapourised refrigerant (water). The refrigerant is then released from the absorbent when heated by an external source.



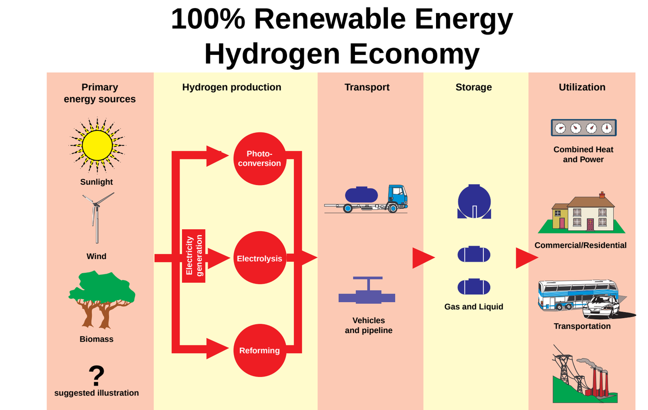
Conventional CHP



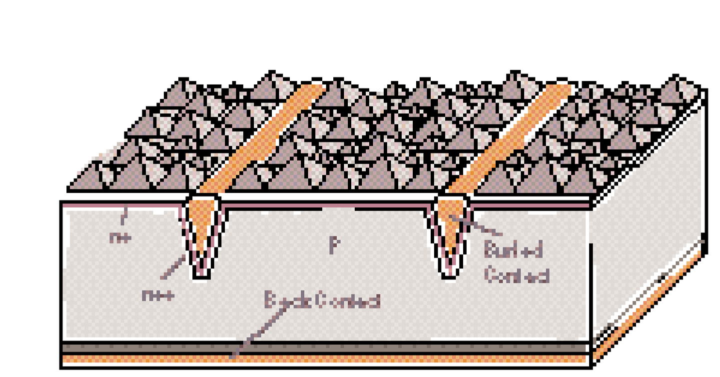
Emerging Hydrogen Economy



100% Renewable Energy Hydrogen Economy



BP Solar



High-efficiency LGBG cell

In the Laser grooved Buried Grid (LGBG) cell narrow grooves are formed in the top wafer surface using a laser and plated with copper to form a conductive grid. The shadowing off the top surface is less than with screen printed contacts allowing more of the incident light to be collected. Improved light collection is also achieved through the inclusion of an antireflection coating and selective phosphorus doping of the silicon in the groove minimising resistive losses. In combination this results in a 20% increase in output power for a given cell area.